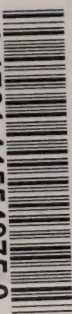


3 1761 11554975 0



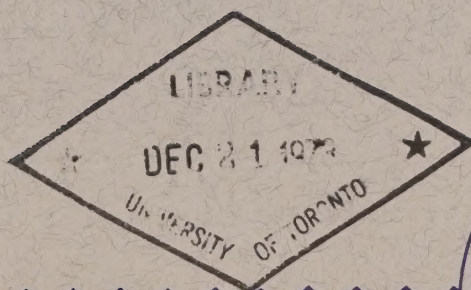


Digitized by the Internet Archive
in 2022 with funding from
University of Toronto

<https://archive.org/details/31761115549750>

SALINITY CALCULATIONS FROM IN SITU MEASUREMENTS

R. G. Perkin, E. R. Walker



ENVIRONMENT CANADA
Water Management Service
Marine Sciences Directorate
Pacific Region
1230 Government St.
Victoria, B.C.

CAI EP 321
-71R01

MARINE SCIENCES BRANCH, PACIFIC REGION

PACIFIC MARINE SCIENCE REPORT NO. 71-1

SALINITY CALCULATIONS FROM IN SITU MEASUREMENTS

R.G. Perkin and E.R. Walker

Marine Sciences Branch
Department of the Environment

December 13, 1971

TABLES

1. Ranges of salinity, temperature and pressure in published experimental data.
2. Brown-Allentoft average experimental salinities minus values obtained from our approximation using the same values of R_T (from Table A1, Appendix 1).
3. Brown-Allentoft average experimental salinity values at 15° C. minus values obtained from our equations 5 and 6 using values of R_{15} given by Brown-Allentoft.
4. International Oceanographic Tables salinity minus values from our approximation using values of R'_T from the tables (Table A3, Appendix 1).
5. Reeburgh's experimental salinities minus values from our equations using values of $C(S,T,0)$ from Reeburgh's Tables.
6. Brown-Allentoft average experimental salinity values minus those calculated by Ribe-Howe "shallow" equation using values of R_{15} from Brown-Allentoft (Table A2, Appendix 1).
7. International Oceanographic Tables salinities minus values calculated from the Ribe-Howe "shallow" equation using values of R'_{15} from the International Tables (Table A4, Appendix 1).

Abstract

A new approximation to the salinity-conductivity relationship suitable for use on a small electronic calculator is presented. The equations developed represent numerical fits to the experimental data of Brown and Allentoft with pressure corrections after Bradshaw and Schleicher. For temperatures from freezing to $+20^{\circ}\text{C}$., salinities from 5‰ to 40‰, and pressures to 1700 db, the error with respect to the data fitted should be less than $\pm 0.01\%$. While intended for use with in situ salinometers in the Canadian Arctic, the equations may prove useful for others working in cool estuarial waters. The approximation is compared to other recent formulations, and estimated error magnitudes are shown for various ranges of temperature and salinity.

Introduction

Values of temperature and salinity observed by us in waters of the Canadian Arctic Archipelago are shown in Figure 1. Salinity can not be calculated from in situ measurements of temperature and conductivity in such waters by using the International Oceanographic Tables for these tables are valid only above 10°C . This note discusses a new numerical approximation to recently published data, which in effect extends the temperature-conductivity-salinity relationships down to freezing temperatures.

Several recent reviews of the history and problems of salinity determinations are available (Cox 1963, Carritt 1963). Traditionally salinity has been empirically related to chlorinity. With recent improvements in electronics it has become feasible to measure electrical conductivity to high accuracy. An early body of experimental data relating conductivity and temperature to chlorinity and salinity was that of Thomas et al (1934). Pollak (1954) noted errors in these data and devised a corrected empirical formula connecting chlorinity, conductivity and temperature. Weyl (1964) also provided an empirical fit to the data of Thomas et al.

Reeburgh (1965) measured conductivity versus chlorinity using Red Sea water, diluted; his are the only data published extending to temperatures colder than 0°C . Cox et al (1967) have recently published a large body of data which forms the basis for the new International Oceanographic Tables (Unesco 1966). Brown and Allentoft (1966) have recently determined conductivity and salinity relationships for sea water diluted with distilled water.

The effect of pressure on the electrical conductivity of sea water has been investigated by Hamon (1958) and Bradshaw and Schleicher (1965). Unpublished work by Mays (1968) and Ettle (private communication, 1970) has confirmed the findings of Bradshaw and Schleicher.

The above constitutes the published experimental data. The range of values of temperature and salinity in each body of experimental data is shown in Table 1. To use this data it is necessary to devise a suitable functional relationship of the form:

$$S = f (C, T, p)$$

where the conductivity, C , may conveniently be given as a ratio of the conductivity, in situ, to that at standard salinity, pressure and temperature.

Equations based on the data of Thomas et al (op. cit.) derived by Weyl (op. cit.) and Pollak (op. cit.) do not contain pressure dependence. The approximating equations in Cox et al (op. cit.) and the International Tables seem intended for use with laboratory salinometers as no pressure effects are included and the temperature ranges extend down only to 10° C. Brown and Allentoft's data covers a wide range of temperatures and salinity values, and they have developed expressions for the average relationship between salinity and the ratio of in situ conductivity to that of sea water at 35/‰. Indication of temperature dependence of the relationship is given but no pressure effects are included.

To meet the relatively restricted ranges of temperatures and salinities met in the arctic winter Armstrong and Lewis (unpublished) extrapolated Reeburgh's data to cover a temperature range of -1.9° C. to 1° C., and salinity range about 29 to 36/‰. For use in a small electronic calculator a simple equation was derived from this data and for in situ data a pressure effect correction was added.

Equations of Ribe and Howe (1967) are based on the International Tables, measurements by Brown and Allentoft and pressure effects data of Bradshaw and Schleicher. Error analyses performed by Ribe and Howe over ranges of 0° C. to 25° C., 30/‰ to 40/‰ in salinity and 0 to 7000 db suggest this range of validity for their equations. The tables supplied with the Guildline C.T.D. units used by the Group were calculated from Ribe and Howe's equation. Our numerical and laboratory analysis led to discovery of systematic errors in the Guildline Tables below 0° C. This was confirmed by experimental work at National Research Council, Ottawa, (Dauphinee, personal communication) as shown in Figure 2. R. A. Lake of

our Group fitted the simple polynomial to Dauphinee's results giving a correction to the Ribe-Howe equation and Guildline Tables of form:

$$\Delta S(\text{‰}) = \delta((-3.6 + 5.0T - 2.45 T^2) \times 10^{-3}) \quad \begin{matrix} \delta = 1 & -2^\circ < T < 1^\circ \text{ C.} \\ \delta = 0 & T > 1^\circ \text{ C.} \end{matrix} \quad (1)$$

This brief review of the ranges of values available in published experimental data and approximations thereto indicates a real need for a new approximation for use in the ranges of values encountered in the Arctic. The only experimental data covering these ranges are those of Brown and Allentoft, Reeburgh, and Dauphinee's work at temperatures below 0° C. For checking values in the field, and for much of the calculation in the home laboratory a small electronic calculator, the HP9100 is used by the Group. To fit this machine a simple approximation to Brown and Allentoft's data with Bradshaw and Schleicher pressure effects included was carried out by Perkin. Only limited use was made of Reeburgh's data as they were not completely compatible with the more extensive Brown and Allentoft data.

Empirical Fit

The numerical fit to Brown and Allentoft's data was, for convenience, made in a number of steps. The first step, correction for the effect of pressure, was taken from the data of Bradshaw and Schleicher; the second step, the formation of the conductivity ratio, from data of Brown and Allentoft and Reeburgh; the third the reduction of the ratio to its value at 0° C. , from data of Brown and Allentoft; and the last step, a fit to Brown and Allentoft's values of salinity versus conductivity ratio. One can enter at step one, with an in situ measurement of conductance, temperature and pressure, or for zero pressure, at step three with a temperature and conductivity ratio. For temperatures below 1° C. , the correction contained in equation (1) must be added.

Bradshaw and Schleicher's data was fitted over ranges $0^\circ \text{ C.} < T < 10^\circ \text{ C.}$, $0 \text{ db.} < p < 1700 \text{ db.}$, $31\text{‰} < S < 35\text{‰}$. While restricted, these values adequately represent conditions found in the waters of the Canadian Arctic Archipelago. Water depths in the Canadian Archipelago are less than 1,000 m. As in most estuarial situations, low salinities are associated with shallow depths. The simple equation resulting, for conductivity at atmospheric pressure, $C(S,T,0)$, from in situ conductivity, $C(S,T,p)$ was:

$$\frac{C(S,T,p)}{C(S,T,0)} = 1 + p \left[49436 + 1567T + 21.33T^2 + 554.43C(S,T,p) \right]^{-1} \quad (2)$$

where the units are $p(\text{db})$, $T(^{\circ}\text{C.})$, $S(\text{‰})$, and $C(\text{mmho.cm.}^{-1})$.

To obtain maximum accuracy in the region of our greatest interest the fit was designed around conductivity at 0° C. Interpolation in Reeburgh's data gave $C(35,0,0) = 29.03916 \text{ mmho.cm.}^{-1}$. Identifying this value as that at 0° C. in Brown and Allentoft's data the conductivity at other temperatures was approximated as:

$$C(35,T,0) = C(35,0,0) \left(1 + .0297175T + .00015551T^2 - .000000789T^3 \right) \quad (3)$$

Using equation (3) we can then, from our value of $C(S,T,0)$ obtain a ratio

$$R_T = C(S,T,0)/C(35,T,0) = C(S,T,0) / \left(29.03916 (1 + .0297175T + .00015551T^2 - .000000789T^3) \right) \quad (4)$$

Numerical fits were made to Brown and Allentoft's Table 21 (R_{15} versus average salinity) and Table 23 (deviation of conductivity from 15° value). Appropriate values of R_{15} and corresponding salinities were taken from Table 21. These were then used in Table 23 to obtain corresponding values of R_0 in the form:

$$R_0 = C(S,0,0)/C(35,0,0) = R_T - 10^{-5} \left[6.0 + 380 \sin \pi \left(\frac{R_T + .04}{1.03} \right) + 15 \sin 3\pi \left(\frac{R_T + .04}{1.03} \right) \right] \times [.0777T - .000454T^2 - .000018T^3] \quad (5)$$

Values of R_0 were used with corresponding salinities to form equations for salinity. Obviously for maximum accuracy the equations for R_0 and for salinity should be used together.

Any single salinity equation which would satisfactorily fit a range of conductivity ratios from 0.1 to 1.2 was too large for the limited capacity of our small calculator. Therefore the fit was done in two pieces as follows:

$$S(‰) = -.5933 + 32.4822 R_0 + 3.1106 R_0^2 + .004 \sin 2\pi \left(\frac{R_0 - .64}{.57} \right) \quad (0.40 \leq R_0 < 1.20) \quad (6)$$

$$S(‰) = -.2166 + 30.686 R_0 + 5.247 R_0^2 \quad (0.10 \leq R_0 < 0.40)$$

With conductivity measuring devices furnishing values of R_T rather than values of C , equations (5) and (6) can be used directly.

Error Analysis

Analysis of the fit of equation (2) to Bradshaw and Schleicher's Table 1 indicates a maximum difference in salinity of about 0.001‰ , over the ranges of salinity, temperature and depth found in Canadian arctic waters. We consider this good enough for our purposes. At the edge of the fit at $p = 1700$ db the difference in salinity from Bradshaw and Schleicher's tables was about 0.003‰ . For other conditions Bradshaw and Schleicher's work might be used directly.

The fit of our equation (3) to Brown and Allentoft's Table 24 (variation of 35‰ sea water conductivity with temperature) is such that over temperatures from 0°C . to 20°C . the error in the ratio of conductivity to conductivity at 15°C . is less than 1×10^{-5} . The fit of our equations to the Brown and Allentoft data from which they were made is shown in Table 2. All calculations were made on a Hewlett-Packard 9100 desk calculator. On the few occasions when interpolation was needed a Gaussian routine supplied with the HP9100 was used. The values on the abscissa are the experimental values. The fit over temperatures from freezing to 20°C . and salinities from 4 to 40‰ is within $\pm 0.007\text{‰}$. Therefore at or below 20°C . the equations can be used for in situ measurements, and also calibration by bench induction salinometers within errors of this size. In Table 3 the same comparison is made in more detail at 15°C .

In Table 4 are results when our equations are used with values of R_T from the International Tables. Agreement is adequate at salinities near 35‰ but there are systematic and rather large differences at lower salinities. These differences reflect the experimental methods used in each case, as noted by Cox et al (op. cit.). Brown and Allentoft diluted sea water with distilled water while Cox diluted with natural sea water. This is also shown, for $T = 15^{\circ}\text{C}$., $p = 0$ db. in Figure 3.

These differences reflect of course a practical problem in that all parts of the ocean do not have quite the same ionic composition. As procedures in this note are intended for use in the Canadian Arctic we intend to use our approximation to Brown and Allentoft's data until more information is available on ionic composition of waters in the archipelago.

In Table 5 our procedures were compared with Reeburgh's data. Reeburgh's values of chlorinity were converted to salinity by Knudsen's equation. The values reflect the systematic difference in the variation of conductivity with salinity between Reeburgh's data and those of Brown and Allentoft. Presumably this is due to differences in the sea waters used by Brown and Allentoft, and the Red Sea water used by Reeburgh.

The tables presently in use with the Guildline instrument are based on those equations of Ribe and Howe (op. cit.) appropriate to shallow depths. A comparison of Brown and Allentoft's average experimental values and those calculated from Ribe-Howe's equation is shown in Table 6. The range of temperature and salinity values used in formulating Ribe and Howe's equation is unknown to the authors, but their error analyses covered $30\text{‰} < S < 40\text{‰}$, $0^{\circ}\text{C.} < T < 40^{\circ}\text{C.}$ In Table 6 the fit is good over this range but differences increase towards lower salinities. At salinities of $30 - 35\text{‰}$ and temperatures from 0°C. to -2°C. agreement in Table 6 is good. This indicates that our fit and Ribe and Howe's fit are extrapolated below 0°C. in the same manner. Therefore the low temperature correction in equation (1) will also be necessary in our procedure. The Ribe and Howe equations include pressure effect corrections. As both their procedures and ours depend on the work of Bradshaw and Schleicher they agree well in this regard so comparisons are not included in this note. The fit of the Ribe and Howe equation to the International Table values, shown in Table 7, is good in the range around 35‰ , but as in Table 6 systematic differences occur towards lower salinities. It is unfair, of course, to extrapolate their equation to low salinities, and it is done only as a warning against such extrapolation. It is understood that Mr. Ribe is working on a version valid over a wider range of salinity. At the moment, while excellent for most oceanic work, their equations are perhaps not as suitable for the wide range of salinities found in estuarial situations.

In Appendix 1 are given the intermediate results leading to the tables quoted above. The values of the conductivities are also included. These latter depend on both the absolute value from Reeburgh as well as the variations with salinity and temperature from Brown and Allentoft's data. The same value of $C(35, T, 0)$ as used in the equations should, of course, be used to calibrate the user's conductivity instruments.

Conclusions

We have developed a simple procedure using equations (2), (4), (5), (6), (1) for calculating salinity from measured conductivity, temperature and pressure. For temperatures below 0°C. the correction in equation (1) is necessary. The procedures are valid over a temperature range of freezing to $+20^{\circ}\text{C.}$, a salinity range of about 4‰ to 40‰ , and down to pressures of 1700 db. The absolute error within these ranges is less than 0.01‰ with respect to the averaged data from which the procedures were derived.

While this is adequate for our purpose a more elaborate fit could produce smaller errors. Indeed Table 2, (or Table 4 for the International Tables), could be used for further correction.

It seems a pity that a universal procedure has not yet been devised and agreed upon as applicable to all in situ measurements and laboratory calculations. The International Oceanographic Tables, which have been adopted as standard, should be extended to freezing temperatures. This might be done without change to the present definition of salinity as a function of R_{15} . It seems to the authors that, in the interim, it might be worth considering adoption of an agreed fit to the body of recent experimental data.

References

- Bradshaw, A., and K. E. Schleicher, 1965. The effect of pressure on the electrical conductance of sea water. *Deep Sea Res.*, 12: 151-162.
- Brown, N. L., and B. Allentoft, 1966. Salinity, conductivity and temperature relationship of sea water and over the range 0-50 PPT. Final report March 1. Prepared for the United States Office of Naval Research. Contract NONr 4290 (00) M.J.O. No. 2003 Bissett-Berman.
- Carritt, D. E., 1963. Chemical Instrumentation. The Sea. V2, M. N. Hill, Editor, Interscience Publishers Division, John Wiley & Sons, New York, 109-123, pp. 554.
- Cox, R. A., 1963. The Salinity Problem. Progress in Oceanography. V1, M. Sears, Ed., The Macmillan Co., New York, 243-261, pp. 383.
- Cox, R. A., F. Culkin, and J. P. Riley, 1967. The electrical conductivity/chlorinity relationship in natural sea water. *Deep Sea Res.* 14: 203-220.
- Hamon, B. V., 1958. The effect of pressure on the electrical conductivity of sea water. *Jour. Marine Res.* V16, No. 2: 83-89.
- Mays, M. E., 1968. Effect of pressure on the ionic conductance through the upper 2000 meters of the ocean's water column. Unpublished. Thesis (M.Sc.) in oceanography, U.S. Naval Postgraduate School, Monterey, Calif.
- Pollak, M. J., 1954. The use of electrical conductivity measurements for chlorinity determination. *Jour. Marine Res.* 13: 228-231.
- Reeburgh, W. S., 1965. Measurements of electrical conductivity of sea water. *Jour. Marine Res.* V23, No. 6: 187-199.
- Ribe, R. L., and J. G. Howe, 1967. An empirical equation relating sea water salinity, temperature, pressure and electrical conductivity. Unpublished report, Oceanographic Instrumentation Center, Naval Oceanographic Office, U.S.A.
- Thomas, B. D., T. G. Thompson, and C. L. Utterback, 1934. The electrical conductivity of sea water. *Jour. Cons. Int. Explor. Mer.* 9: 28-35.
- Unesco, 1966. International Oceanographic Tables. Unesco. Place de Fontenoy, Paris 7e, France. National UNESCO Office of Oceanography, Institute of Oceanography, Great Britain, Wormley, England. pp. 128.
- Weyl, P. K., 1964. On the change in electrical conductance of sea water with temperature. *Limnol. & Oceanogr.*, 9: 75-78.

TABLE 1

RANGE OF VALUES IN DATAData

Thomas et al	$0^{\circ} < T < 20^{\circ} \text{ C.}; 10 < S < 35^{\circ}/_{\text{oo}};$ $T = 25^{\circ}; 3 < S < 39^{\circ}/_{\text{oo}};$	$p = 0$ $p = 0$
Reeburgh	$-1 < T < 35^{\circ} \text{ C.}; 28 < S < 40^{\circ}/_{\text{oo}};$	$p = 0$
Cox et al	$T = 15^{\circ}; 25 < S < 41^{\circ}/_{\text{oo}};$ $14 < T < 29; 4 < S < 42^{\circ}/_{\text{oo}};$	$p = 0$ $p = 0$
Brown and Allentoft	$0 < T < 30^{\circ}; 2 < S < 40^{\circ}/_{\text{oo}};$ $T = 15^{\circ}; 0 < S < 60^{\circ}/_{\text{oo}};$ $0 < T < 35^{\circ}; S = 35^{\circ}/_{\text{oo}};$	$p = 0$ $p = 0$ $p = 0$
Dauphinee	$-2 < T < 0; 30 < S < 35^{\circ}/_{\text{oo}};$	$p = 0$
Bradshaw and Schleicher	$T = 0, 5, 10, 15, 20, 25^{\circ} \text{ C.}$ $S = 31, 35, 39$ $p = 0 - 10,338 \text{ db}$	

TABLE 2

S (‰)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	.018	-.008	-.005	-.012	-.008	-.005	-.003	.000	.011
20	.020	-.004	.001	-.004	-.002	-.000	.000	.000	.009
15	.020	-.004	.002	-.003	-.002	-.000	.002	.001	.002
10	.018	-.005	.001	-.003	-.003	-.000	.003	.002	-.001
5	.015	-.006	.000	-.003	-.003	-.001	.004	.002	-.001
+2	.013	-.007	.001	-.002	-.003	-.001	.004	.003	-.002
+1	.012	-.007	.002	-.002	-.003	-.000	.004	.003	-.002
0	.012	-.007	.003	-.002	-.003	-.000	.004	.003	-.002
-1	.011	-.008	.004	-.002	-.003	.001	.003	.004	-.002
-2	.011	-.008	.005	-.002	-.003	.001	.002	.004	-.002

1. C. F.

2. Brown-Allentoft average experimental salinities minus values obtained from our approximation using the same values of R_T (from Table A1, Appendix 1), ‰.

TABLE 3

<u>R₁₅</u>	<u>B/A</u>	<u>Salinity</u> <u>Eqns. 5,6</u>	<u>Difference</u> <u>B/A-Our Eqns.</u>
.00	0.0000	-.154	+.154
.05	1.3831	1.344	.039
.10	2.8783	2.875	.003
.15	4.4359	4.440	-.004
.20	6.0381	6.040	-.002
.25	7.6775	7.675	+.003
.30	9.3477	9.344	+.004
.35	11.0458	11.049	-.003
.40	12.7694	12.768	+.001
.45	14.5165	14.519	-.003
.50	16.2852	16.289	-.004
.55	18.0748	18.078	-.003
.60	19.8846	19.886	-.001
.65	21.9122	21.713	-.001
.70	23.5564	23.557	-.001
.75	25.4208	25.420	+.001
.80	27.3027	27.301	+.002
.85	29.2017	29.200	+.002
.90	31.1176	31.116	+.002
.95	33.0504	33.049	+.001
1.00	35.0000	34.999	+.001
1.05	36.9665	36.966	+.000
1.10	38.9498	38.949	+.001
1.15	40.9504	40.947	+.003
1.20	42.9674	42.958	+.009

3. Brown-Allentoft average experimental salinity values at 15° C. minus values obtained from our equations 5 and 6 using values of R₁₅ given by Brown-Allentoft.

TABLE 4

S (°/‰) (Unesco)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	-.002	-.034	-.045	-.040	-.023	-.011	-.004	.000	.017
20	-.001	-.030	-.037	-.032	-.018	-.007	-.001	.000	.011
15	-.002	-.029	-.036	-.032	-.019	-.009	-.002	.001	.009
10	-.005	-.032	-.040	-.038	-.025	-.014	-.005	.002	.008

5

(°/‰) F

+2

+1

0

-1

-2

4. International Oceanographic Table salinity minus values from our approximation using values of R'_T from the tables (Table A3, Appendix 1), ‰.

TABLE 5

S (‰) (from Reeburgh)

	28.910	30.715	32.520	34.325	36.130	37.930
19	.005	.005	.003	.000	-.004	-.014
15	.004	.005	.004	.001	-.004	-.014
9	.005	.004	.004	.002	-.003	-.013
5	.002	.005	.005	.002	-.002	-.013
1	.004	.005	.005	.004	-.002	-.012
0	.006	.007	.006	.004	-.002	-.013
-1	.007	.007	.006	.004	-.001	-.013

(‰) F

5. Reeburgh's experimental salinities minus values from our equations using values of $C(S, T, 0)$ from Reeburgh's Tables, ‰.

TABLE 6

S (°/‰)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	.900	.635	.272	.111	.045	.012	.001	-.001	-.007
20	.895	.635	.275	.115	.050	.017	.004	.001	-.004
15	.878	.622	.270	.113	.048	.016	.004	-.001	-.008
10	.843	.594	.255	.108	.046	.018	.006	.000	-.009
5	.770	.536	.221	.091	.039	.016	.009	.001	-.007
+2	.698	.476	.185	.069	.028	.012	.007	.000	-.007
+1	.667	.450	.169	.060	.022	.010	.006	.000	-.007
0	.632	.420	.150	.047	.015	.006	.004	-.001	-.007
-1	.592	.387	.129	.034	.008	.005	.003	.000	-.005
-2	.547	.348	.105	.019	-.001	.001	.000	.000	-.005

6. Brown-Allentoft average experimental salinity values minus those calculated by Ribe-Howe "shallow" equation using values of R_{15} from Brown-Allentoft (Table A2, Appendix 1) † ‰/‰.

TABLE 7

S (‰)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	.877	.608	.231	.082	.031	.008	.001	.000	.000
20	.872	.607	.235	.086	.033	.009	.002	.000	.000
15	.855	.595	.230	.082	.031	.007	.001	.000	.000
10	.817	.565	.212	.073	.023	.003	-.001	.000	.001

5

(‰)

+2

+1

0

-1

-2

7. International Oceanographic Tables salinities minus values calculated from the Ribe-Howe "shallow" equation using values of R'15 from the International Tables (Table A4, Appendix 1), ‰.

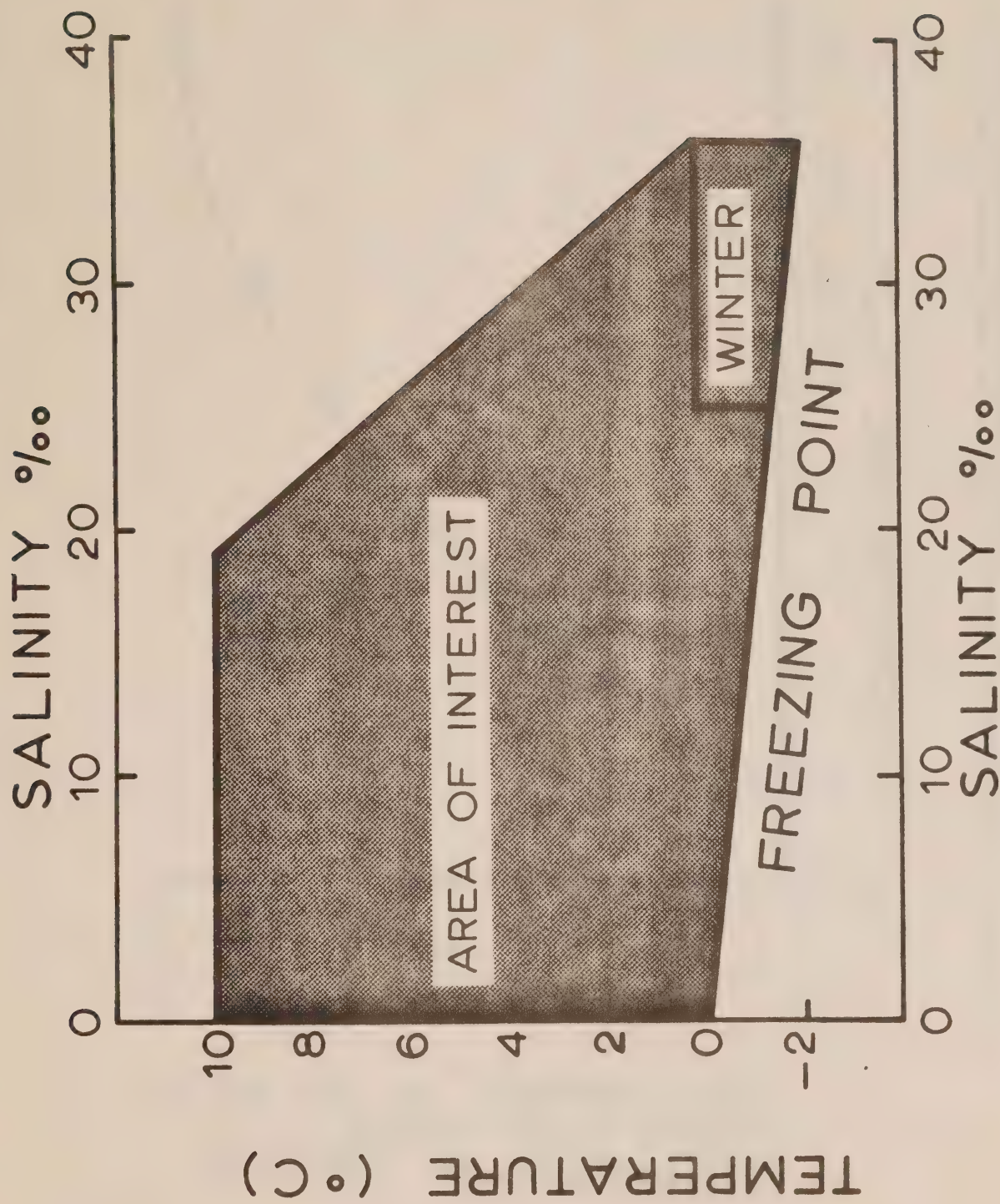


Fig. 1. Range of temperature and salinity values observed in the waters of the Canadian Arctic Archipelago.

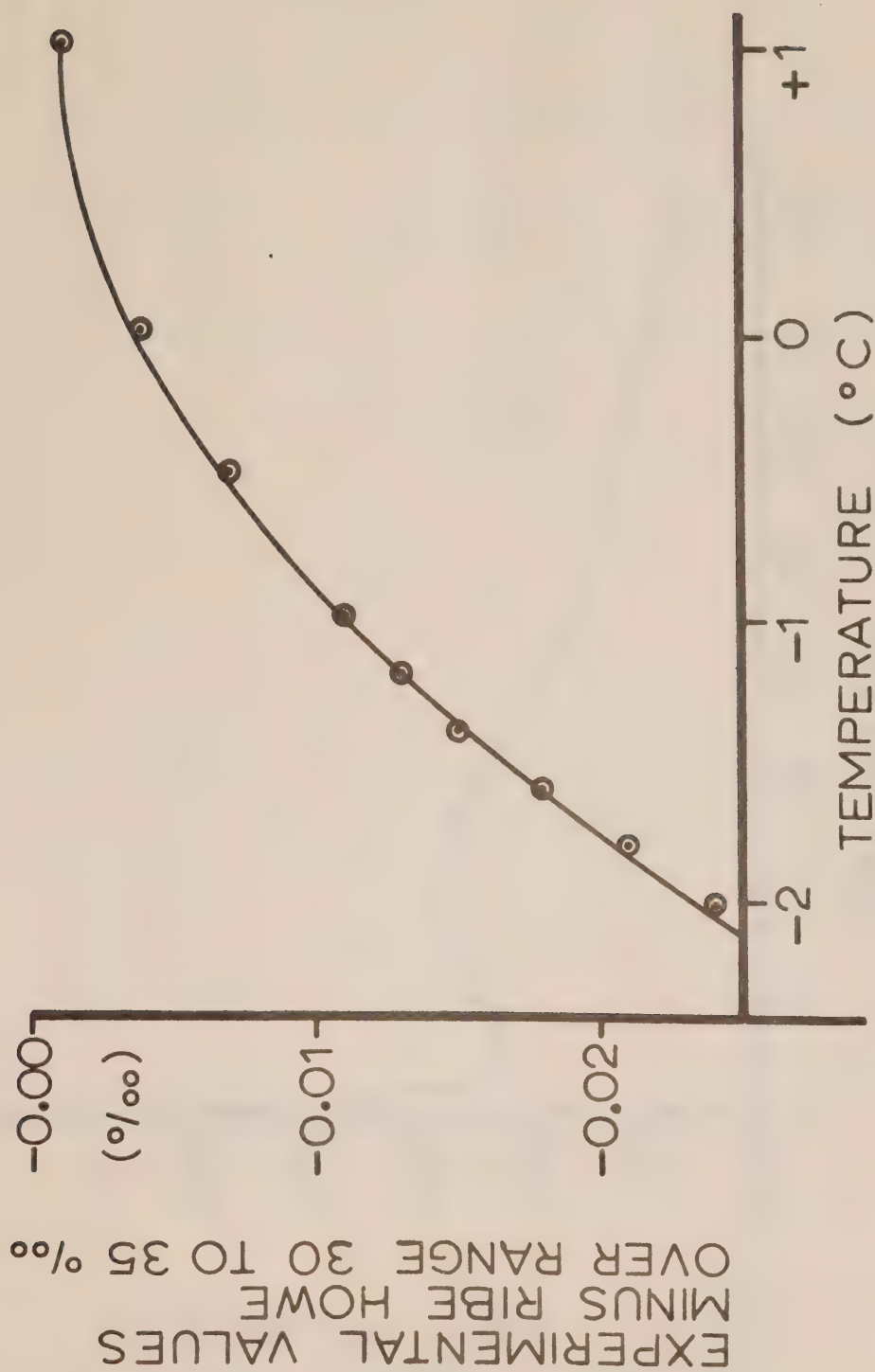


Fig. 2. Correction to Ribe-Howe equation for temperatures below $+1^{\circ}\text{C}.$, based on experimental work by Dauphinee (unpublished). Simple fit by R.A. Lake is also given by line.

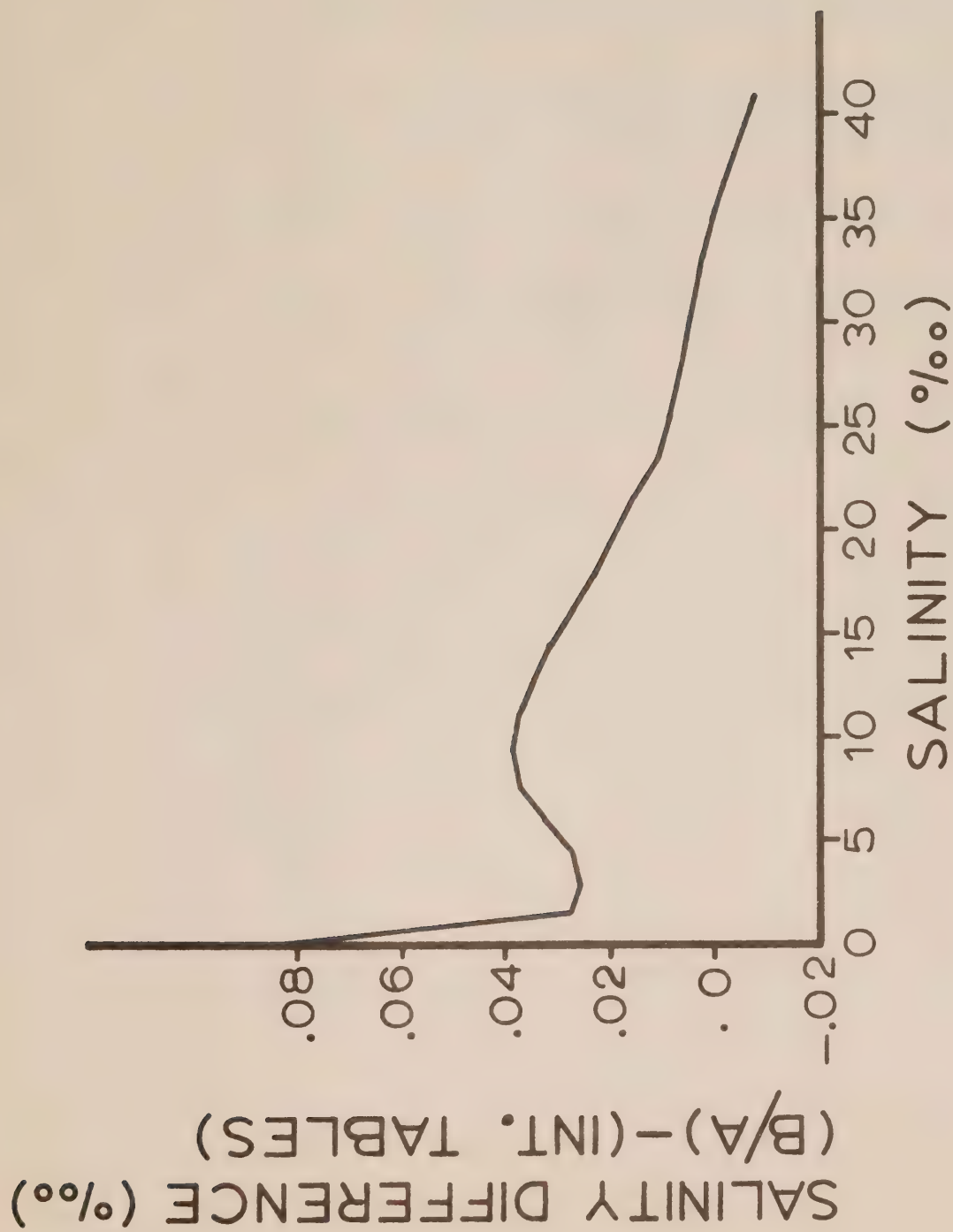


Fig. 3. Differences between Brown and Allentoft mean salinity data and salinities computed from the UNESCO tables using Ratios $R_{15} = C(S,15,0)/C(35,15,0)$ from Brown and Allentoft.

APPENDIX 1

APPENDIX I

TABLES OF INTERMEDIATE RESULTS

- A 1. Values of $R_T = C(S, T, 0)/C(35, T, 0)$ from Brown-Allentoft Table 23 using HP9100 Gaussian Interpolation routine for values at 2, 1, -1, -2 °C.
- A 2. Values of $R_{15} = C(S, T, 0)/C(35, 15, 0)$ formed by multiplying values in Table A1 by factor $C(35, T, 0)/C(35, 15, 0)$ from Brown-Allentoft Table 24.
- A 3. Values of $R'_T = C(S, T, 0)/C(35, T, 0)$ from Equations in International Tables using given values of T, S.
- A 4. Values of $R'_{15} = C(S, T, 0)/C(35, 15, 0)$ from International Table Values of R_T multiplied by factor $C(35, T, 0)/C(35, 15, 0)$ from Ribe-Howe (R_0).
- A 5. Values of $C(S, T, 0)$ from Table A 2 using $C(35, 0, 0) = 29.03916$ from Reeburgh's values and $C(35, 0, 0)/C(35, 15, 0) = 0.67654$ from Brown-Allentoft Table 24.
- A 6. Values of S using our equations 5 and 6 on values of R_T in Table A 1.
- A 7. Values of S using our equations 5 and 6 on values of R'_T in Table A 3.
- A 8. Values of S from Ribe-Howe "Shallow" equation using R_{15} from Table A 2.
- A 9. Values of S from Ribe-Howe "Shallow" equation on values of R'_{15} from Table A 4.

TABLE A 1

		S (°/°°)								
		1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
H	25	.06911	.14232	.31662	.47858	.61290	.74879	.87679	1.00000	1.13035
	20	.06884	.14185	.31593	.47782	.61221	.74825	.87650	1.00000	1.13071
	15	.06853	.14134	.31511	.47696	.61142	.74763	.87611	1.00000	1.13120
	10	.06818	.14074	.31417	.47588	.61045	.74684	.87567	1.00000	1.13176
	5	.06779	.14003	.31303	.47461	.60928	.74594	.87512	1.00000	1.13234
	+2	.06754	.13956	.31225	.47378	.60850	.74533	.87479	1.00000	1.13271
	+1	.06745	.13940	.31197	.47350	.60823	.74511	.87468	1.00000	1.13284
F	0	.06736	.13924	.31169	.47321	.60796	.74489	.87458	1.00000	1.13297
	-1	.06727	.13908	.31140	.47292	.60768	.74466	.87448	1.00000	1.13310
	-2	.06718	.13891	.31110	.47263	.60740	.74442	.87439	1.00000	1.13324

A 1. Values of $R_T = C(S, T, O)/C(35, T, O)$ from Brown-Allentoft Table 23 using HP9100 Gaussian Interpolation routine for values at 2, 1, -1, -2 ° C.

TABLE A 2

S (°/°)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	.08546	.17600	.39154	.59182	.75792	.92597	1.08426	1.23662	1.39781
20	.07685	.15837	.35272	.53346	.68350	.83538	.97857	1.11645	1.26238
15	.06853	.14134	.31511	.47696	.61142	.74763	.87611	1.00000	1.13120
10	.06051	.12492	.27885	.42238	.54182	.66287	.77722	.88757	1.00452
5	.05285	.10917	.24405	.37002	.47501	.58156	.68227	.77963	.88281
+2	.04844	.10009	.22394	.33979	.43641	.53454	.62739	.71719	.81236
+1	.04700	.09713	.21737	.32991	.42379	.51916	.60944	.69676	.78931
0	.04557	.09420	.21087	.32015	.41131	.50395	.59169	.67654	.76650
-1	.04416	.09130	.20443	.31047	.39894	.48886	.57409	.65649	.74387
-2	.04277	.08844	.19806	.30090	.38671	.47394	.55669	.63666	.72149

F
(°C.)

A 2. Values of $R_{15} = C(S, T, 0)/C(35, 15, 0)$ formed by multiplying values in Table A1 by factor $C(35, T, 0)/C(35, 15, 0)$ from Brown-Allentoft Table 24.

TABLE A 3

		S (°/°)									
		1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196	
25	.06979	.14314	.31779	.47938	.61330	.74893	.87681	1.00000	1.13022		
20	.06952	.14266	.31705	.47862	.61265	.74844	.87653	1.00000	1.13059		
15	.06923	.14215	.31625	.47778	.61190	.74788	.87622	1.00000	1.13102		
10	.06892	.14160	.31538	.47686	.61107	.74723	.87586	1.00000	1.13152		
5								1.00000			
+2											
+1											
0											
-1											
-2											

A 3. Values of $R'_T = C(S, T, 0)/C(35, T, 0)$ from Equations in International Tables using given values of T, S.

TABLE A 4

S (°/°°)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	.08630	.17700	.39297	.59279	.75839	.92611	1.08425	1.23658	1.39761
20	.07762	.15928	.35398	.53437	.68401	.83562	.97863	1.11648	1.26228
15	.06923	.14215	.31624	.47777	.61188	.74787	.87620	.99998	1.13100
10	.06117	.12568	.27992	.42325	.54237	.66322	.77739	.88757	1.00430

5
(°/°°)

+2

+1

0

-1

-2

A 4. Values of $R'_{15} = C(S,T,0)/C(35,15,0)$ from International Table Values of R_T multiplied by factor $C(35,T,0)/C(35,15,0)$ from Ribe-Howe (R_0).

TABLE A 5
S (°/°)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	3.668	7.554	16.806	25.403	32.532	39.745	46.540	53.080	59.998
20	3.299	6.798	15.140	22.898	29.338	35.857	42.003	47.921	54.185
15	2.942	6.067	13.525	20.473	26.244	32.091	37.605	42.923	48.555
10	2.597	5.362	11.969	18.130	23.257	28.452	33.361	38.097	43.117
5	2.268	4.686	10.475	15.882	20.389	24.962	29.285	33.464	37.893
+2	2.079	4.296	9.612	14.585	18.732	22.944	26.929	30.784	34.869
+1	2.017	4.169	9.330	14.161	18.190	22.284	26.159	29.907	33.880
0	1.956	4.043	9.051	13.742	17.655	21.631	25.397	29.039	32.901
-1	1.895	3.919	8.775	13.326	17.124	20.983	24.642	28.179	31.929
-2	1.836	3.796	8.501	12.916	16.599	20.343	23.895	27.327	30.969

A 5. Values of C(S,T,0) from Table A 2 using C(35,0,0) = 29.03916 from Reeburgh's values and C(35,0,0)/C(35,15,0) = 0.67654 from Brown-Allentoft Table 24.

TABLE A 6

S ‰

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	1.909	4.171	9.863	15.480	20.308	25.337	30.203	35.000	40.185
20	1.907	4.167	9.857	15.472	20.302	25.332	30.200	35.000	40.187
15	1.907	4.167	9.856	15.471	20.302	25.332	30.198	34.999	40.194
10	1.909	4.168	9.857	15.471	20.303	25.332	30.197	34.998	40.197
5	1.912	4.169	9.858	15.471	20.303	25.333	30.196	34.998	40.197
+2	1.914	4.170	9.857	15.470	20.303	25.333	30.196	34.997	40.198
+1	1.915	4.170	9.856	15.470	20.303	25.332	30.196	34.997	40.198
0	1.915	4.170	9.855	15.470	20.303	25.332	30.196	34.997	40.198
-1	1.916	4.171	9.854	15.470	20.303	25.331	30.197	34.996	40.198
-2	1.916	4.171	9.853	15.470	20.303	25.331	30.198	34.996	40.198

A 6. Values of S using our equations 5 and 6 on values of R_T in Table A 1.

TABLE A 7

		S (°/°) (Unesco)								
		1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	1.929	4.197	9.903	15.508	20.323	25.343	30.204	35.000	40.179	
20	1.928	4.193	9.895	15.500	20.318	25.339	30.201	35.000	40.185	
15	1.929	4.192	9.894	15.500	20.319	25.341	30.202	34.999	40.187	
10	1.932	4.195	9.898	15.506	20.325	25.346	30.205	34.998	40.188	
5										
+2										
+1										
0										
-1										
-2										

A 7. Values of S using our equations 5 and 6 on values of R'_T in Table A 3.

TABLE A 8

S (°/°)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	1.027	3.528	9.586	15.357	20.255	25.320	30.199	35.001	40.203
20	1.032	3.528	9.583	15.353	20.250	25.315	30.196	34.999	40.200
15	1.049	3.541	9.588	15.355	20.252	25.316	30.196	35.001	40.204
10	1.084	3.569	9.603	15.360	20.254	25.314	30.194	35.000	40.205
5	1.157	3.627	9.637	15.377	20.261	25.316	30.191	34.999	40.203
+2	1.229	3.687	9.673	15.399	20.272	25.320	30.193	35.000	40.203
+1	1.260	3.713	9.689	15.408	20.278	25.322	30.194	35.000	40.203
0	1.295	3.743	9.708	15.421	20.285	25.326	30.196	35.001	40.203
-1	1.335	3.776	9.729	15.434	20.292	25.327	30.197	35.000	40.201
-2	1.380	3.815	9.753	15.449	20.301	25.331	30.200	35.000	40.201

A 8. Values of S from Ribe-Howe "Shallow" equation using R_{15} from Table A 2.

TABLE A 9

S ($^{\circ}/_{\circ\circ}$)

	1.927	4.163	9.858	15.468	20.300	25.332	30.200	35.000	40.196
25	1.050	3.555	9.627	15.386	20.269	25.324	30.199	35.000	40.196
20	1.055	3.556	9.623	15.382	20.267	25.323	30.198	35.000	40.196
15	1.072	3.568	9.628	15.384	20.269	25.325	30.199	35.000	40.196
10	1.110	3.598	9.646	15.395	20.277	25.329	30.201	35.000	40.195

5

(°/°)

+2

F

+1

0

-1

-2

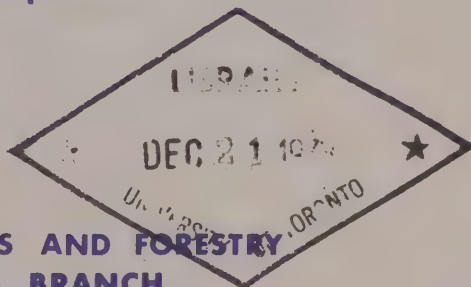
A 9. Values of S from Ribe-Howe "Shallow" equation on values of R'15 from Table A 4.

©
INFORMATION CANADA
OTTAWA 1973

**OCEANOGRAPHIC OBSERVATIONS AT
OCEAN STATION P (50°N, 145°W)
VOLUME 45
January 9 - May 21, 1970**

**C. de Jong, R. Bellegay, D.A. Healey
Marine Sciences Branch
Department of Fisheries and Forestry**

**J.H. Linggard, Master, CCGS VANCOUVER
and
A.A.R. Dykes, Master, CCGS QUADRA
Marine Services Branch
Ministry of Transport**



**DEPARTMENT OF FISHERIES AND FORESTRY
MARINE SCIENCES BRANCH
PACIFIC REGION
512 FEDERAL BLDG
VICTORIA, B.C.**



MARINE SCIENCES BRANCH, PACIFIC REGION

PACIFIC MARINE SCIENCE REPORT NO. 71-2

OCEANOGRAPHIC OBSERVATIONS AT OCEAN STATION P (50°N, 145°W)

VOLUME 45

JANUARY 9 - MAY 21, 1970

by

C. de Jong, R. Bellegay, D.A. Healey

Marine Sciences Branch
Department of Fisheries and Forestry

J.H. Linggard
Master, CCGS VANCOUVER

and

A.A.R. Dykes
Master, CCGS QUADRA

Marine Services Branch
Ministry of Transport

<u>Survey Dates</u>	<u>Title and Data Record Listing</u>	<u>Volume</u>
July 3 - Sept. 14, 1967	CODC 1968 No. 9	32
Sept. 15 - Dec. 7, 1967	CODC 1969 No. 3	33
Dec. 3, 1967 - Feb. 28, 1968	CODC 1969 No. 6	34
Feb. 23 - May 23, 1968	CODC 1969 No. 10	35
May 17 - Aug. 15, 1968	CODC 1969 No. 12	36
 <u>Oceanographic Observations At Ocean Station "P" (50°N., 145° W.)</u>		
Aug. 9 - Sept. 26, 1968	Fisheries Research Board of Canada Manuscript Report Series No. 1047	37
Oct. 27, 1968 - Feb. 26, 1969	Fisheries Research Board of Canada Technical Report No. 143	38
Feb. 21 - Apr. 9, 1969	FRB Tech. Rept. No. 145	39
Apr. 4 - May 22, 1969	FRB Tech. Rept. No. 153	40
May 16 - July 3, 1969	FRB Tech. Rept. No. 154	41
June 27 - Sept. 25, 1969	FRB Tech. Rept. No. 184	42
Oct. 31 - Dec. 10, 1969	FRB Tech. Rept. No. 194	43
Sept. 19, 1969 - Jan. 15, 1970	FRB Tech. Rept. No. 211	44

FISHERIES RESEARCH BOARD MANUSCRIPT REPORT SERIES

ERRATA

TO

Manuscript Report Series No. 1047

Nansen Bottle and S.T.P. Data Computed Using Incorrect Expression For Gravity. Observed Data (Temp., Sal., Oxygen, Depth) Not Affected.

Manuscript Report Series No. 1071

Page 75: Gravity Subprogram Should Read:
 $(XAT * XAT * (-XAT * 1.4189E-7) + 1.9155E-5)) + 9.78030$

FISHERIES RESEARCH BOARD TECHNICAL REPORT SERIES

ERRATA

TO

Technical Report No. 143

Page 30: Last Press and Depth Should Read: 965-960
Nansen Bottle and S.T.P. Data Computed Using Incorrect
Expression For Gravity. Observed Data (Temp., Sal., Oxygen,
Depth) Not Affected.

Technical Report No. 145

Page 25: Time Should Read: GMT 15.2
Page 105: Date Should Read: 15/6/68
Page 107: Date Should Read: 15/6/68

Nansen Bottle and S.T.P. Data Computed Using Incorrect Expression
For Gravity. Observed Data (Temp., Sal., Oxygen, Depth) Not
Affected.

Technical Report No. 152

Page 18: Gravity Statement Should Read:
$$\text{GRAV} = (\text{YLAT} * \text{YLAT} * ((-\text{YLAT} * 1.4189\text{E}-7) + 1.9155\text{E}-5)) + 9.78030$$

Technical Report No. 154

Page 84: Position Should Read: 50-6.0 N.
144-58.0 W.
Page 92: Position Should Read: 50-2.8 N.
145-7.7 W.
Page 119: Date Should Read: 16/6/69
Page 129: Latitude Should Read: 49-56.5 N.
Page 220: Longitude Should Read: 144-50.0 W.

Technical Report No. 184

Page 17: Date Should Read: 8/7/69
Page 79: Longitude Should Read: 146-06.0 W.
Page 181: Time Should Read: GMT 05.1

Technical Report No. 211

Page 31: Time Should Read: GMT 01.7

Technical Report No. 194

Page 2: Survey Should Read: P-69-8
Page 14: Date Should Read: 29/11/69

In order to assist in library cataloguing it has been decided to assign volume numbers to this data series. The volume numbers to be assigned to the previous data are as follows:

<u>Survey Dates</u>	<u>Title and Data Record Listing</u>	<u>Volume</u>
	<u>Data Record Ocean Weather Station "Papa" (Latitude 50°00'N., Longitude 145°00'W.)</u>	
Aug. 21 - Dec. 19, 1956	Fisheries Research Board of Canada Data Record 1956	1
Jan. 1, 1957 - Jan. 24, 1958	Fisheries Research Board of Canada Oceanographic & Limnological Manuscript Report Series No. 14	2
	<u>Data Record Ocean Weather Station "P" (Latitude 50°00'N., Longitude 145°00'W.)</u>	
Jan. 22 - July 11, 1958	FRB O & L No. 31	3
July 9, 1958 - Jan. 24, 1959	FRB O & L No. 44	4
Jan. 21 - Nov. 24, 1959	FRB O & L No. 59	5
Dec. 9, 1959 - Jan. 19, 1961	FRB O & L No. 98	6
	<u>Oceanographic Data Record Ocean Weather Station "P"</u>	
Jan. 18 - Sept. 17, 1961	FRB O & L No. 106	7
Sept. 12, 1961 - Jan. 21, 1962	FRB O & L No. 125	8
Jan. 17 - Aug. 5, 1962	FRB O & L No. 139	9
Aug. 1, 1962 - Jan. 18, 1963	FRB O & L No. 154	10
Oceanographic Atlas, 1956 - 1963	FRB O & L No. 187	11

Survey DatesTitle and Data Record ListingVolumeData Record Series Ocean Weather
Station "P" North Pacific Ocean

Jan. 15 - April 10, 1963	Canadian Oceanographic Data Centre 1963 Data Series No. 2	12
April 10 - June 28, 1963	CODC 1963 No. 3	13
June 25 - Sept. 13, 1963	CODC 1963 No. 6	14
Sept. 11 - Nov. 29, 1963	CODC 1964 No. 5	15
Dec. 4, 1963 - Feb. 24, 1964	CODC 1964 No. 15	16
Feb. 22 - April 2, 1964	CODC 1964 No. 20	17
May 16 - Aug. 12, 1964	CODC 1965 No. 3	18
Aug. 7 - Oct. 31, 1964	CODC 1965 No. 7	19
Oct. 31, 1964 - Jan. 26, 1965	CODC 1965 No. 8	20
Jan. 23 - April 19, 1965	CODC 1966 No. 1	21
April 17 - July 1, 1965	CODC 1966 No. 3	22
July 2 - Sept. 22, 1965	CODC 1966 No. 5	23
Sept. 17 - Dec. 15, 1965	CODC 1966 No. 6	24
Dec. 11, 1965 - Mar. 9, 1966	CODC 1966 No. 8	25
Mar. 3 - June 2, 1966	CODC 1966 No. 11	26
May 27 - Aug. 10, 1966	CODC 1967 No. 5	27
Aug. 5 - Oct. 31, 1966	CODC 1967 No. 6	28
Oct. 28, 1966 - Jan. 9, 1967	CODC 1967 No. 8	29
Jan. 16 - April 12, 1967	CODC 1968 No. 2	30
Apr. 7 - July 6, 1967	CODC 1968 No. 5	31

INTRODUCTION

Canadian operation of Ocean Weather Station P (latitude 50°00'N, longitude 145°00'W) was inaugurated in December, 1950. The station is manned by two vessels operated by the Marine Services Branch of the Department of Transport. They are the CCGS VANCOUVER and the CCGS QUADRA. Each ship remains on station for a period of six weeks, and is then relieved by the alternative ship, thus maintaining a continuous watch. The chief purpose of the station is to operate as a meteorological station for surface and upper-air observations and as an air-sea rescue station.

Bathythermograph observations have been made at Station P since July, 1952. A program of more extensive oceanographic observations was commenced in August, 1956. This was further extended in April, 1959 by the addition of a series of oceanographic stations along the route to and from Station P and Swiftsure Bank. The number of stations on this line has been increased twice and now consists of twelve stations (Fig. 1). Data observed prior to 1968 has been indexed by Collins et al, (1969).

The present record includes hydrographic data and salinity-temperature-pressure data collected from the QUADRA during the period January 9 to February 26, 1970 and salinity-temperature-pressure data collected from the VANCOUVER during the period February 20 to April 9, 1970 and from the QUADRA during the period April 3 to May 21, 1970. Mechanical bathythermograph traces obtained on these cruises are available on IBM microfiche cards and will be available in digitized format on magnetic tape in the near future.

All physical data has been archived by the Canadian Oceanographic Data Centre (CODC), 615 Booth Street, Ottawa, Ontario. Requests for these data should be directed to CODC.

Program of observations from CCGS QUADRA, January 9 - February 26, 1970
(P-70-1) (CODC Ref. No. 02-70-001)

Oceanographic observations were made by Mr. C. de Jong and Mr. R. Bellegay of the Department of Fisheries and Forestry, Marine Sciences Branch.

En route to Station P, stations 3 through 12 were occupied. A Bissett-Berman 9006 STD with a digital data logger system was used to obtain continuous temperature and salinity records from the surface to (approximately) 1500 meters. Each STD station was accompanied by a mechanical BT cast to 275 meters. BT casts were also made at odd meridians at 40', e.g. 129°40'W, 131°40'W, etc.

On Station P profiles of salinity, temperature and oxygen were obtained as follows:

- I) Weekly Nansen bottle casts to near bottom.
- II) STP casts to 1500 meters immediately after each Nansen bottle cast.
- III) 300 meter STD casts twice weekly.
- IV) The STD was lowered through the halocline every 10 minutes for one 24 hour period.
- V) Mechanical BT casts were made 8 times daily and a bucket salinity sample was taken daily at 0000 hours GMT.

On two occasions an AMF Acoustic Release System was tested at 4200 meters.

Vertical zooplankton hauls from 150 m depth were made daily on station, and from 1200 meters twice during the patrol. Horizontal zooplankton tows were made at the beginning, middle and end of the patrol. Ocean productivity measurements of photosynthesis rate (C_{14} method) and plant pigment concentration were made at frequent intervals during the survey. Biological and productivity data are published in the manuscript report series of the Fisheries Research Board of Canada and all requests for data should be addressed to Fisheries Research Board of Canada, The Biological Station, Nanaimo, B.C., Canada.

Duplicate air samples for carbon dioxide analysis were collected weekly on station. Water samples (from the seawater loop) were collected three times for oceanic surface ^{14}C analysis.

Six separate 15 gallon samples of seawater were collected at depths of 50, 100, 150, 200, 300 and 500 meters for the oceanic ^{14}C studies of Dr. Fairhall of the University of Washington, Seattle, Washington, U.S.A.

Bird observations were made three times daily and a marine mammal log was kept. The bird observations were sent to Dr. M. Myres of the University of Calgary, Calgary, Alberta, Canada and the marine mammal log was forwarded to Mr. I. McAskie at the Fisheries Research Board of Canada's Biological Station, Nanaimo, B.C., Canada.

En route from Station P, stations 5 through 1 were occupied. Each station consisted of a STD cast, a mechanical BT cast and the collection of a surface salinity and nitrate sample.

Program of observations from CCGS VANCOUVER, February 20 - April 9, 1970
(P-70-2) (CODC Ref. No. 02-70-002)

Observations on this patrol were made by Capt. Linggard and his officers of the Marine Services Branch, Department of Transport.

En route to Station P mechanical BT observations were made at 125°30'W, 126°00'W, 126°40'W and at each meridian at 40' thereafter e.g. 127°40'W, 128°40'W etc.

At Station P profiles of salinity and temperature were obtained as follows:

- 1) STP casts to 300 meters were made 2 or 3 times a week and to 1500 meters once a week using a Bissett-Berman Model 9040 STD.
- 11) Mechanical BT casts were made 8 times daily and a bucket salinity sample was taken at 0000 hrs. GMT daily.

Vertical zooplankton hauls from 150 meters were made daily and one haul from 4200 meters was made during the patrol. Frequent 10 minute surface zooplankton tows were made and surface nitrate samples were collected every second day.

Duplicate air samples were collected weekly on station for carbon dioxide analysis. Bird observations were made 3 times daily, and a marine mammal log was kept. No observations were made en route from Station P.

Program of observations from CCGS QUADRA, April 3 - May 21, 1970 (P-70-3) (02-70-003)

Oceanographic observations on this patrol were made by Capt. Dykes and his officers of the Marine Sciences Branch, Department of Transport.

At Station P profiles of temperature and salinity were obtained as follows:

- 1) STP casts to 300 meters were made 2 or 3 times a week and to 1500 meters once a week using a Bissett-Berman Model 9006 STD.
- 11) Mechanical BT casts were made 8 times daily and a bucket salinity sample was taken at 0000 hrs. GMT daily.

Vertical zooplankton hauls from 150 meters were made daily, weather permitting. Frequent 10 minute surface zooplankton tows were made and surface nitrate samples were taken every second day. Three rainwater samples were collected and air samples in duplicate were collected weekly for carbon

dioxide analysis. Bird and marine mammal observations were made on this patrol. No observations were made en route from Station P.

The production of this technical report was supervised by Mr. D.A. Healey, Oceanographer of the Marine Sciences Branch, Department of Fisheries and Forestry.

Data was processed by Mr. D.A. Healey and Mr. D. Smith, and assembled and edited for publication by Mr. K. Abbott-Smith.

Observational procedures

Temperatures at depth were measured by deep-sea reversing thermometers of German (Richter and Wiese) or Japanese (Yoshino Keiki Co.) manufacture. Two protected thermometers were used on all Nansen bottles, and one unprotected thermometer was used on each bottle at depths of 300 m or greater. The accuracy of protected reversing thermometers is believed to be $\pm 0.02^\circ\text{C}$.

Surface water temperatures were measured from a bucket sample using a deck thermometer of $\pm 0.1^\circ\text{C}$ accuracy.

Salinity determinations were made at sea on cruise P-70-1, and ashore after cruises P-70-2 and P-70-3 using a Bissett-Berman Laboratory Salinometer Model 6220. Accuracy using duplicate determinations is estimated to be ± 0.003 ppt.

Depth determinations were made using the "depth difference" method described in the U.S.N. Hydrographic Office Publication No. 607 (1955). Depth estimates have an approximate accuracy of ± 5 m for depths less than 1000 m, and $\pm 0.5\%$ of depth for depths greater than 1000 m.

The dissolved oxygen analyses were done in the shipboard laboratory by a modified Winkler method (Carpenter, 1965).

Salinity-temperature-pressure data were obtained with a Bissett-Berman Model 9006 STD on cruises P-70-1 and P-70-3, and a Bissett-Berman Model 9040 STD on cruise P-70-2.

Computations

All hydrographic data were processed with the aid of an IBM 360 computer. Reversing thermometer temperature corrections, thermometric depth calculations, and accepted depth from the "depth difference" method were computed. An IBM Plotter was used to plot temperature-salinity and temperature-oxygen diagrams, as well as plots of temperature, salinity and dissolved oxygen vs \log_{10} depth. These plots were used to check the data for errors.

Missing hydrographic data were obtained using a weighted parabolas interpolation method (Reiniger and Ross, 1968). These data are indicated with an asterisk in this data record.

Analog records from the salinity-temperature-pressure instrument have been hand digitized, then replotted using the IBM 1627 Plotter. Digitization was continued until original and computer plotted traces were coincident. Temperature and salinity values were listed at standard pressures; integrals (depth, geopotential anomaly, and potential energy anomaly) were computed from the entire array of digitized data.

STD salinity data have been adjusted to make them compatible with hydrographic cast salinity data. For the period January 9 - February 26, a salinity correction linear with depth was applied. The correction was $-.06$ ppt at 0 m and increased to $-.11$ ppt at 1500 m. Figure 2 compares STD and hydrographic cast salinity data. During the period February 20 - April 9, a linear (with depth) correction of $-.03$ ppt at 0 m and increasing to $-.06$ ppt at 1500 m was applied. For the period April 3 - May 21, two corrections were applied to salinity data. For depths of 0 - 300 m, the linear correction was $+.01$ ppt at 0 m, increasing to $-.05$ ppt at 300 m. For 300 - 1500 m the linear correction was $-.05$ ppt at 300 m, increasing to $-.06$ ppt at 1500 m.

The headings for the data listings are explained as follows:

PRESS	is pressure (decibars)
TEMP	is temperature (degrees Celsius)
SAL	is salinity (parts per thousand)
DEPTH	is reported in meters
SIGMA-T	is specific gravity anomaly
SVA	is specific volume anomaly
THETA	is potential temperature (degrees Celsius)
SVA (THETA)	is potential specific volume anomaly
DELTA D	is geopotential anomaly (J/kg)
POT EN	is potential energy in units of 10^8 ergs/cm ²
GXY	is the concentration of dissolved oxygen expressed in milliliters per liter
V-B PERIOD	is the Väisälä-Brunt period in minutes

Summary of hydrographic data

The data are graphically summarized as follows: composite plot of temperature vs \log_{10} depth (fig. 3), composite plot of salinity vs \log_{10} depth (fig. 4), and composite plot of dissolved oxygen vs \log_{10} depth (fig. 5) for hydrographic cast data from cruise P-70-1.

REFERENCES

- Carpenter, J.H. 1965. The Chesapeake Bay Institute Technique For The Winkler Dissolved Oxygen Method. *Limnol. & Oceaogr.*, 10: 141-143.
- Collins, C.A., R.L. Tripe, D.A. Healey, and D. Joergensen. 1969. The Time Distribution of Serial Oceanographic Data From The Ocean Station P Program. Fisheries Research Board of Canada, Technical Report No. 106.
- Reiniger, R.F. and C.K. Ross. 1968. A Method Of Interpolation With Application To Oceanographic Data. *Deep Sea Res.* 15: 185-193.
- U.S.N. Hydrographic Office. 1955. Instruction Manual For Oceanographic Observations. Publication No. 607.

List of Figures

- Figure 1 Chart showing Line P station positions.
- Figure 2 Profiles of the salinity difference between data obtained with a Bissett-Berman model 9006 STD and from salinity samples from Nansen bottles.
- Figure 3 Composite plot of temperature vs. \log_{10} depth, P-70-1.
- Figure 4 Composite plot of salinity vs. \log_{10} depth, P-70-1.
- Figure 5 Composite plot of dissolved oxygen vs. \log_{10} depth, P-70-1.
- Figure 6 T-S plot of surface temperature and salinity observations on Line P (asterisks) and at Station P (pluses) during Cruise P-70-1.
- Figure 7 T-S plot of surface temperature and salinity observations on Line P (asterisks) and at Station P (pluses) during Cruise P-70-2.
- Figure 8 T-S plot of surface temperature and salinity observations on Line P (asterisks) and at Station P (pluses) during Cruise P-70-3.

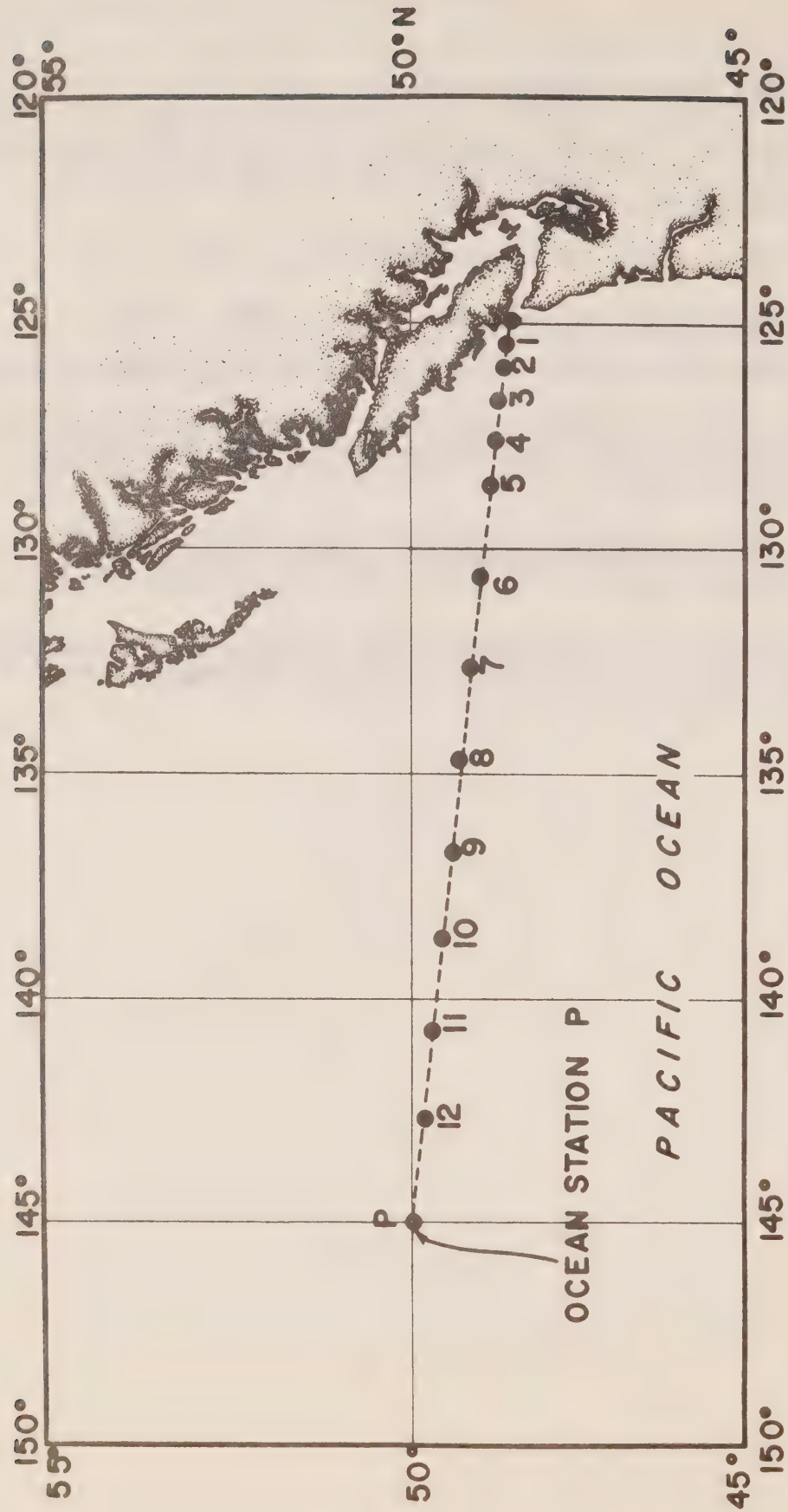


Fig. 1 Chart showing Line P station positions.

SALINITY DIFFERENCE, S.T.D. - NANSEN, ‰

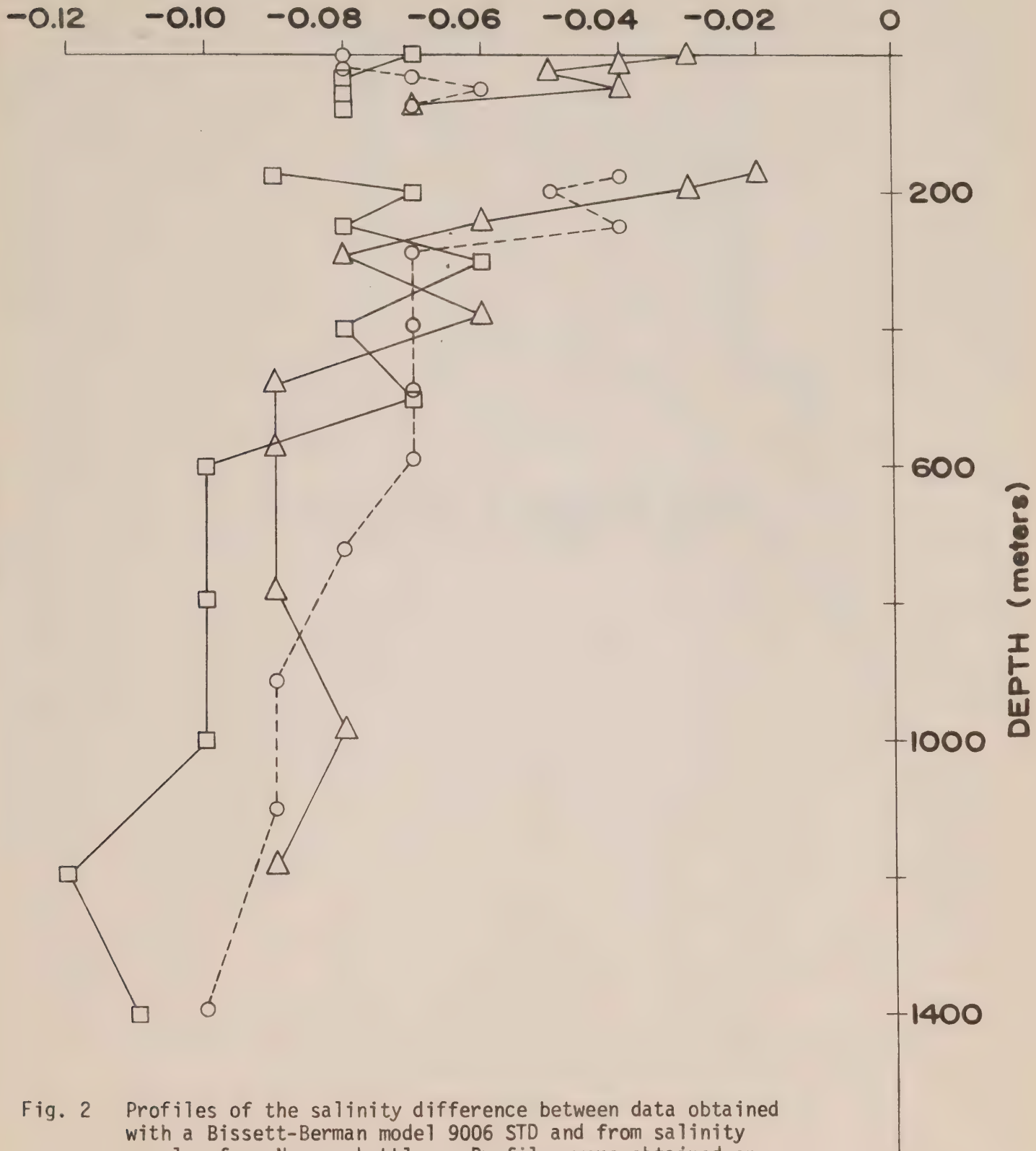


Fig. 2 Profiles of the salinity difference between data obtained with a Bissett-Berman model 9006 STD and from salinity samples from Nansen bottles. Profiles were obtained on the following days: 21 January (triangles), 7 February (squares) and 10 February (circles).

COMPOSITE PLOTS OF TEMPERATURE, SALINITY
AND DISSOLVED OXYGEN VS. DEPTH

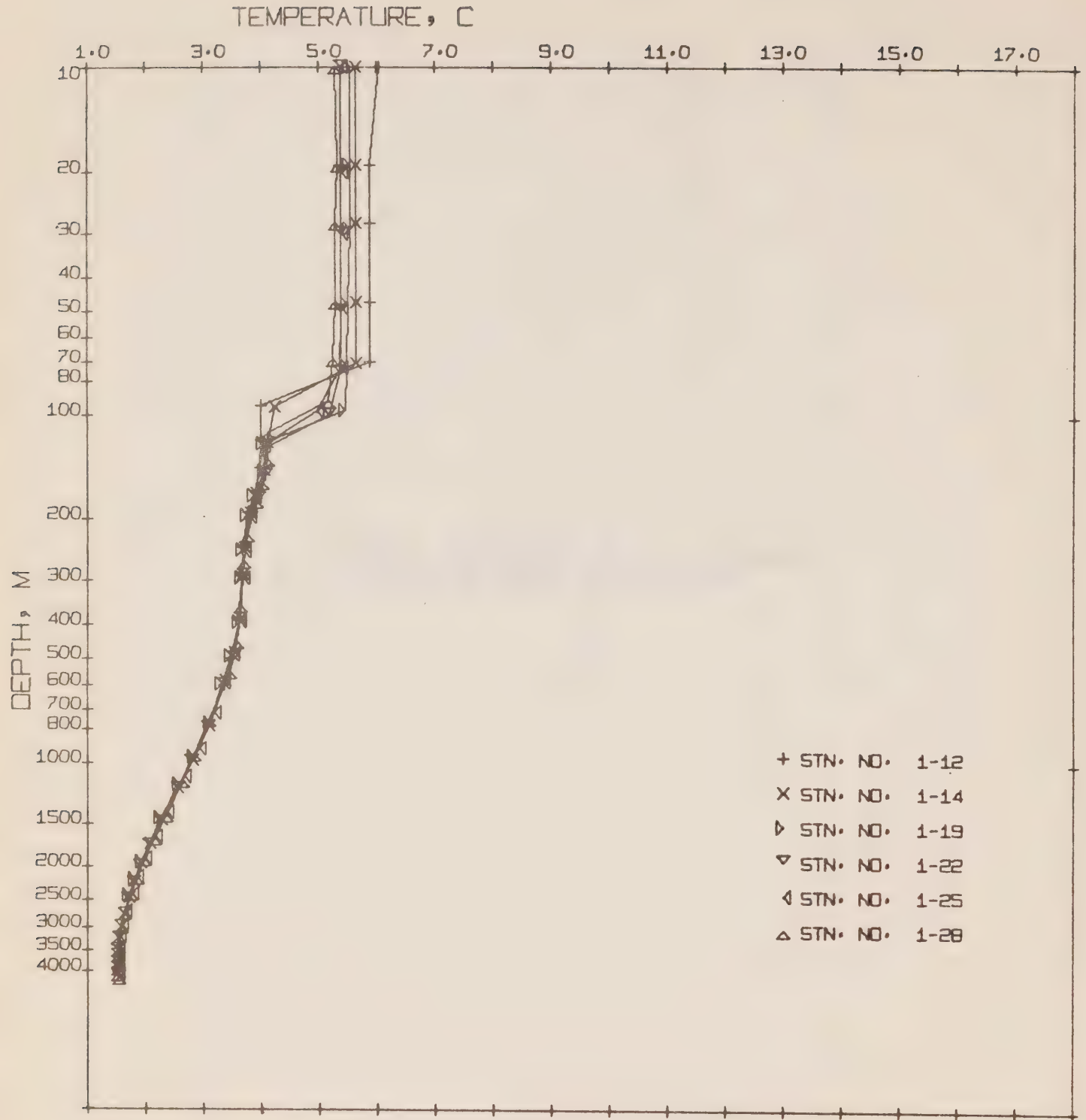


Fig. 3 Composite plot of temperature vs. \log_{10} depth, P-70-1.

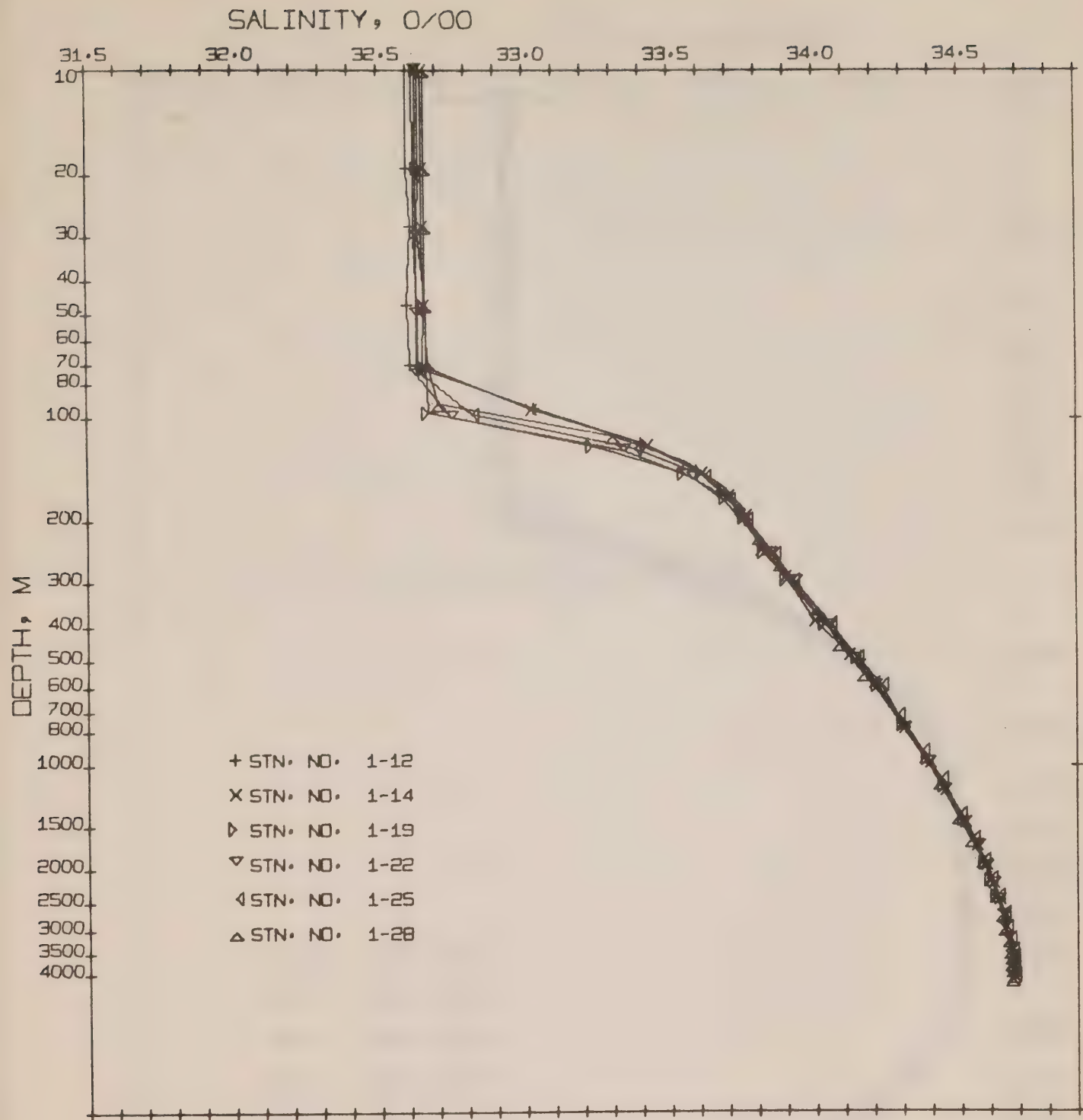


Fig. 4 Composite plot of salinity vs. \log_{10} depth, P-70-1.

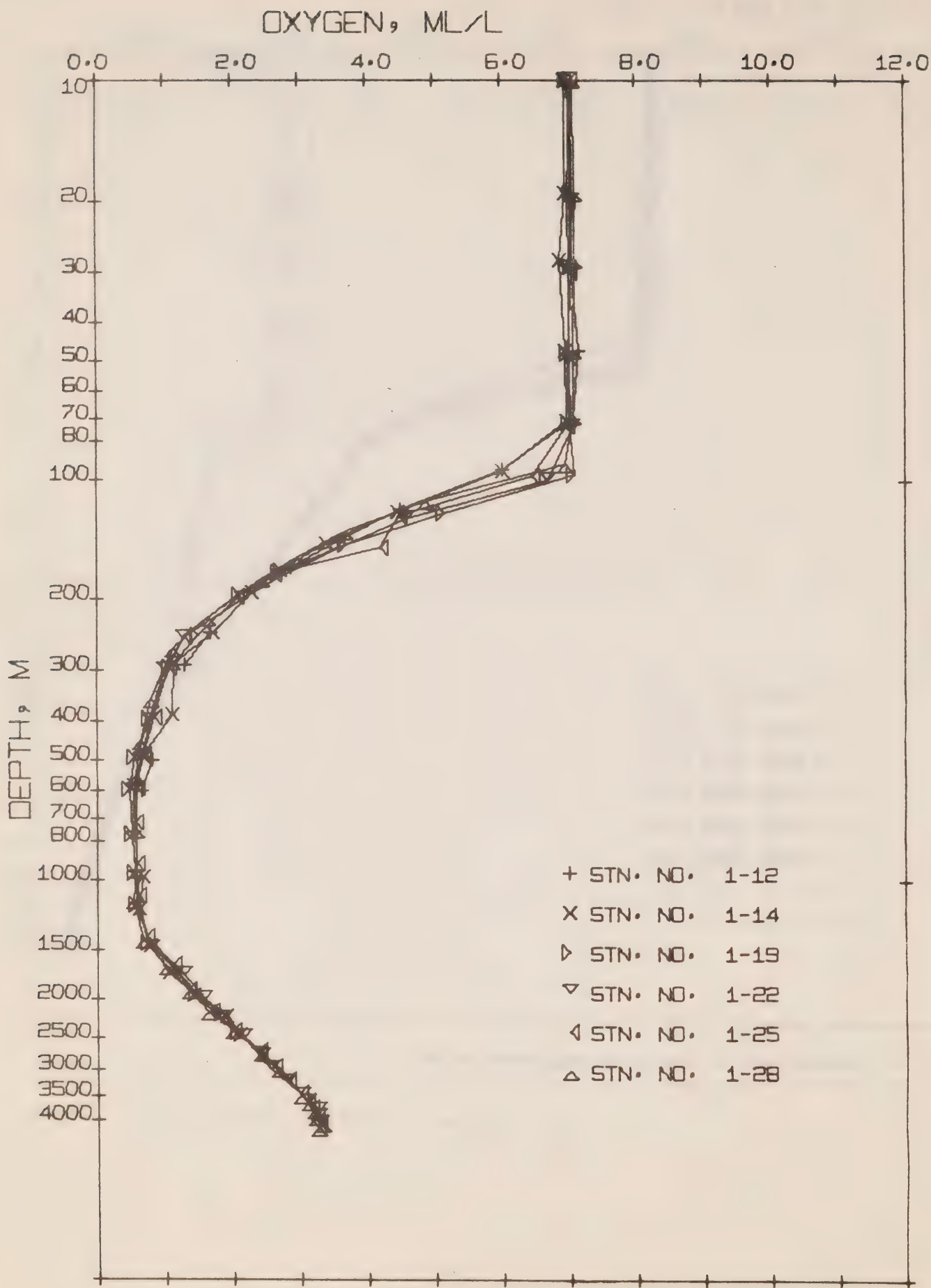


Fig. 5 Composite plot of dissolved oxygen vs. \log_{10} depth, P-70-1.

RESULTS OF NANSEN BOTTLE CASTS
(P-70-1)

PACIFIC OCEANOGRAPHIC GROUP

REFERENCE NO. 70-1-12

DATE 14/ 1/70

POSITION 50- 0.ON, 145- 0.0W

GMT 19.1

HYDROGRAPHIC CAST DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	V-B PERIOD	OXY	SOUND
0	5.87	32.603	0	25.702	229.9	5.87	229.9	0.00	0.00	22	7.03	1471.
10	6.04	32.599	10	25.678	232.6	6.04	232.2	0.23	0.01	177	7.06	1472.
19	5.88	32.602	19	25.700	230.6	5.88	230.1	0.44	0.04	27	7.05	1472.
28	5.88	32.611	28	25.707	230.0	5.88	229.4	0.65	0.09	73	7.05	1472.
47	5.88	32.602	47	25.700	230.9	5.88	230.1	1.09	0.26	171	7.17	1472.
70	5.88	32.610	70	25.706	230.6	5.87	229.5	1.63	0.58	10	7.08	1473.
95	4.00	33.032	94	26.248	179.0	3.99	178.0	2.12	0.99	8	6.02	1466.
119	4.00	33.399	118	26.539	151.6	3.99	150.3	2.52	1.42	11	4.51	1467.
143	3.99	33.594	142	26.695	137.0	3.98	135.5	2.86	1.88	15	3.58	1467.
167	3.92	33.698	166	26.784	128.7	3.91	127.0	3.18	2.39	20	2.88	1467.
192	3.79	33.744	191	26.834	124.2	3.78	122.3	3.50	2.97	26	0.00	1467.
243	3.70	33.825	241	26.907	117.6	3.68	115.3	4.11	4.32	28	1.69	1468.
293	3.68	33.912	291	26.978	111.3	3.66	108.5	4.69	5.90	31	1.31	1469.
393	3.63	34.029	390	27.076	102.7	3.60	99.2	5.76	9.62	33	0.00	1470.
504	3.49	34.158	500	27.192	92.5	3.46	88.1	6.84	14.55	37	0.82	1472.
605	3.36	34.220	600	27.254	87.2	3.32	82.2	7.75	19.67	42	0.67	1473.

PACIFIC OCEANOGRAPHIC GROUP

DATE 21/ 1/70

REFERENCE NO. 70- 1- 14

POSITION 50- 0.0N, 145- 0.0W GMT 20.0

HYDROGRAPHIC CAST DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	V-B PERIOD	OXY	SOUND
0	5.68	32.656	0	25.766	223.8	5.68	223.8	0.00	0.00	149	6.91	1471.
10	5.65	32.652	10	25.767	224.1	5.65	223.7	0.23	0.01	99	6.96	1471.
19	5.65	32.654	19	25.768	224.1	5.65	223.6	0.43	0.04	84	6.96	1471.
28	5.64	32.654	28	25.769	224.1	5.64	223.5	0.63	0.09	132	6.88	1471.
47	5.65	32.655	47	25.769	224.3	5.65	223.5	1.06	0.26	374	6.96	1471.
71	5.64	32.654	71	25.769	224.5	5.63	223.4	1.60	0.58	11	6.99	1472.
96	4.24	33.024	95	26.217	182.0	4.23	180.9	2.09	1.00	8	6.02	1467.
121	4.12	33.424	120	26.547	150.9	4.11	149.6	2.51	1.46	11	4.47	1467.
145	4.07	33.613	144	26.702	136.4	4.06	134.9	2.85	1.92	15	3.40	1468.
169	3.92	33.706	168	26.791	128.1	3.91	126.4	3.17	2.43	20	2.72	1468.
193	3.83	33.763	192	26.845	123.2	3.82	121.2	3.48	3.00	26	2.30	1468.
243	3.72	33.818	241	26.900	118.3	3.70	116.0	4.07	4.32	30	1.73	1468.
291	3.68	33.902	289	26.970	112.0	3.66	109.3	4.63	5.83	31	1.14	1469.
389	3.64	34.001	386	27.053	104.9	3.61	101.4	5.69	9.49	34	1.13	1470.
486	3.55	34.120	482	27.156	95.8	3.52	91.5	6.67	13.82	34	0.71	1472.
583	3.38	34.203	578	27.239	88.6	3.34	83.7	7.56	18.68	40	0.55	1473.
791	3.10	34.309	784	27.349	79.2	3.05	73.1	9.30	30.80	46	0.00	1475.
994	2.82	34.397	984	27.445	70.9	2.75	63.9	10.82	44.54	51	0.68	1477.
1192	2.57	34.450	1180	27.509	65.4	2.49	57.8	12.16	59.57	58	0.63	1480.
1486	2.28	34.517	1470	27.587	58.7	2.18	50.3	13.98	84.35	65	0.78	1483.
1730	2.09	34.556	1710	27.634	54.7	1.97	45.8	15.36	106.96	73	1.07	1487.
1976	1.93	34.588	1952	27.672	51.5	1.79	42.0	16.67	131.60	81	1.43	1490.
2226	1.81	34.614	2198	27.702	49.1	1.66	39.1	17.93	158.51	92	1.91	1494.
2482	1.72	34.631	2449	27.722	47.6	1.54	37.0	19.16	188.12	105	2.10	1498.
2789	1.64	34.648	2750	27.742	46.3	1.44	35.0	20.60	226.80	111	2.44	1503.

PACIFIC OCEANOGRAPHIC GROUP

REFERENCE NO. 70-1-19

DATE 29/ 1/70

POSITION 50- 0.0N, 145- 0.0W

GMT 21.0

HYDROGRAPHIC CAST DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	V-B PERIOD	OXY	SOUND
0	5.56	32.637	0	25.765	223.9	5.56	223.9	0.00	0.00	63	7.00	1470.
10	5.55	32.639	10	25.768	224.0	5.55	223.6	0.23	0.01	77	7.00	1470.
19	5.55	32.640	19	25.769	224.0	5.55	223.5	0.43	0.04	105	7.06	1470.
29	5.55	32.636	29	25.766	224.4	5.55	223.8	0.65	0.10	44	7.06	1471.
48	5.50	32.664	48	25.794	221.9	5.50	221.1	1.08	0.27	39	7.01	1471.
72	5.49	32.663	72	25.794	222.1	5.48	221.1	1.62	0.60	77	7.02	1471.
98	5.47	32.671	97	25.803	221.6	5.46	220.2	2.18	1.08	9	7.10	1471.
122	4.05	33.237	121	26.405	164.3	4.04	163.0	2.64	1.59	8	5.17	1467.
147	4.07	33.554	146	26.655	140.9	4.06	139.3	3.02	2.11	12	3.70	1468.
172	3.89	33.698	171	26.787	128.5	3.88	126.7	3.36	2.66	17	2.70	1467.
196	3.76	33.760	195	26.850	122.7	3.75	120.8	3.66	3.23	24	2.12	1467.
247	3.69	33.830	245	26.912	117.2	3.67	114.9	4.26	4.59	30	1.50	1468.
297	3.67	33.905	295	26.974	111.7	3.65	109.0	4.84	6.19	31	1.09	1469.
397	3.63	34.037	394	27.083	102.2	3.60	98.6	5.91	9.96	33	0.79	1470.
498	3.48	34.148	494	27.185	93.1	3.45	88.8	6.89	14.43	36	0.57	1472.
600	3.33	34.217	595	27.255	87.1	3.29	82.2	7.81	19.57	43	0.49	1473.
777	3.12	34.306	770	27.345	79.5	3.07	73.5	9.28	29.87	47	0.53	1475.
974	2.84	34.387	965	27.435	71.7	2.77	64.9	10.77	43.15	50	0.57	1477.
1170	2.58	34.446	1158	27.505	65.7	2.50	58.2	12.11	57.79	56	0.59	1479.
1465	2.26	34.514	1449	27.586	58.6	2.16	50.4	13.94	82.26	66	0.77	1483.
1959	1.94	34.584	1935	27.668	51.9	1.81	42.4	16.65	129.39	81	1.46	1490.
2205	1.82	34.606	2177	27.695	49.7	1.67	39.8	17.90	155.88	93	1.84	1493.
2453	1.73	34.624	2420	27.716	48.1	1.56	37.6	19.11	184.60	98	2.08	1497.

PACIFIC OCEANOGRAPHIC GROUP
REFERENCE NO. 70- 1- 22
POSITION 50- 0.0N, 145- 0.0W
HYDROGRAPHIC CAST DATA

DATE 7/ 2/70
GMT 10.3

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	V-B PERIOD	OXY	SOUND
0	5.42	32.635	0	25.780	222.5	5.42	222.5	0.00	0.00	70	7.06	1470.
10	5.38	32.632	10	25.782	222.6	5.38	222.2	0.22	0.01	118	7.05	1470.
20	5.38	32.631	20	25.782	222.8	5.38	222.3	0.45	0.05	196	7.06	1470.
30	5.38	32.631	30	25.782	222.9	5.38	222.3	0.67	0.10	153	7.02	1470.
50	5.38	32.633	50	25.783	222.9	5.38	222.1	1.12	0.29	167	7.03	1470.
75	5.37	32.631	75	25.783	223.2	5.36	222.2	1.68	0.65	22	7.05	1471.
101	5.18	32.750	100	25.898	212.5	5.17	211.1	2.24	1.14	9	6.70	1470.
126	4.09	33.345	125	26.487	156.6	4.08	155.3	2.70	1.67	9	4.60	1467.
151	4.08	33.583	150	26.677	138.8	4.07	137.2	3.07	2.19	14	3.52	1468.
176	3.96	33.691	175	26.775	129.7	3.95	127.9	3.41	2.75	19	2.72	1468.
201	3.83	33.750	200	26.835	124.2	3.82	122.2	3.72	3.37	23	2.17	1468.
252	3.70	33.850	250	26.927	115.8	3.68	113.4	4.33	4.76	26	1.28	1468.
302	3.67	33.937	300	26.999	109.3	3.65	106.6	4.90	6.36	31	1.01	1469.
403	3.61	34.053	400	27.097	100.8	3.58	97.2	5.95	10.15	36	0.79	1471.
504	3.53	34.135	500	27.170	94.6	3.50	90.2	6.94	14.71	39	0.66	1472.
605	3.37	34.210	600	27.245	88.1	3.33	83.0	7.86	19.92	41	0.55	1473.
802	3.09	34.308	795	27.350	79.2	3.04	73.1	9.51	31.69	46	0.52	1475.
1005	2.79	34.390	995	27.442	71.2	2.72	64.2	11.02	45.62	52	0.59	1477.
1207	2.56	34.444	1195	27.505	65.8	2.48	58.2	12.41	61.21	59	0.61	1480.
1510	2.26	34.513	1493	27.585	58.9	2.16	50.4	14.29	87.21	63	0.81	1484.
1763	2.06	34.562	1742	27.641	54.1	1.94	45.1	15.72	110.95	73	1.29	1487.
2016	1.91	34.590	1991	27.675	51.3	1.77	41.7	17.05	136.57	86	1.58	1491.
2271	1.81	34.613	2242	27.701	49.3	1.65	39.1	18.33	164.61	95	1.82	1495.
2528	1.71	34.630	2494	27.722	47.7	1.53	37.0	19.57	195.04	104	2.16	1498.
2784	1.64	34.643	2745	27.738	46.6	1.44	35.4	20.78	227.68	121	2.38	1502.
3037	1.58	34.647	2993	27.745	46.3	1.36	34.5	21.96	262.57	124	2.56	1506.
3291	1.54	34.662	3241	27.760	45.4	1.29	32.9	23.12	300.03	131	2.81	1511.
3546	1.53	34.670	3490	27.768	45.3	1.26	32.1	24.27	340.31	153	3.03	1515.
3698	1.52	34.674	3639	27.772	45.3	1.23	31.6	24.97	365.86	177	3.11	1518.
3853	1.52	34.675	3790	27.772	45.7	1.21	31.4	25.67	392.97	207	3.26	1520.
4008	1.52	34.677	3941	27.774	45.9	1.20	31.2	26.38	421.39	229	3.25	1523.
4164	1.53	34.678	4093	27.774	46.4	1.19	31.1	27.10	451.40	380	3.29	1526.
4269	1.55	34.680	4195	27.774	46.9	1.20	31.0	27.59	472.41	749	3.25	1528.

PACIFIC OCEANOGRAPHIC GROUP

DATE 10/ 2/70

REFERENCE NO. 70- 1- 25

GMT 17.5

POSITION 50- 0.0N, 145- 0.0W

HYDROGRAPHIC CAST DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	V-B PERIOD	OXY	SOUND
0	5.42	32.620	0	25.768	223.6	5.42	223.6	0.00	0.00	43	7.01	1470.
10	5.38	32.622	10	25.774	223.4	5.38	223.0	0.22	0.01	57	7.04	1470.
20	5.38	32.623	20	25.775	223.4	5.38	222.9	0.45	0.05	95	7.01	1470.
30	5.38	32.625	30	25.777	223.3	5.38	222.8	0.67	0.10	66	7.02	1470.
49	5.39	32.635	49	25.784	222.9	5.39	222.1	1.10	0.28	69	7.03	1470.
73	5.38	32.637	73	25.786	222.9	5.37	221.8	1.64	0.61	17	6.99	1471.
99	4.96	32.822	98	25.980	204.6	4.95	203.4	2.18	1.09	9	6.46	1470.
124	4.05	33.380	123	26.519	153.6	4.04	152.2	2.63	1.59	9	4.48	1467.
149	3.97	33.619	148	26.717	135.0	3.96	133.5	2.99	2.09	14	4.21	1467.
174	3.89	33.704	173	26.792	128.0	3.88	126.3	3.32	2.64	20	2.63	1467.
198	3.80	33.766	197	26.850	122.7	3.79	120.7	3.63	3.21	23	2.06	1468.
249	3.70	33.862	247	26.937	114.9	3.68	112.5	4.22	4.57	29	1.29	1468.
298	3.63	33.925	296	26.999	110.3	3.66	107.6	4.78	6.12	32	1.07	1469.
396	3.62	34.052	393	27.095	100.9	3.59	97.4	5.81	9.77	34	0.84	1470.
494	3.51	34.146	490	27.181	93.5	3.48	89.2	6.77	14.08	37	0.69	1472.
595	3.35	34.227	590	27.261	86.6	3.31	81.6	7.67	19.11	42	0.58	1473.
727	3.18	34.284	720	27.322	81.4	3.13	75.7	8.78	26.52	48	0.56	1474.
918	2.93	34.368	909	27.412	73.8	2.87	67.1	10.26	38.93	49	0.58	1476.
1111	2.66	34.433	1100	27.488	67.2	2.53	59.8	11.62	52.96	56	0.61	1479.
1405	2.36	34.497	1390	27.564	60.7	2.27	52.5	13.49	76.92	65	0.73	1482.
1655	2.16	34.540	1636	27.615	56.4	2.05	47.5	14.95	99.67	71	1.13	1486.
1909	1.99	34.577	1886	27.658	52.8	1.86	43.3	16.34	124.80	79	1.35	1489.
2168	1.85	34.601	2141	27.688	50.3	1.70	40.4	17.67	152.53	90	1.69	1493.
2433	1.75	34.623	2401	27.714	48.4	1.58	37.9	18.98	183.15	96	2.00	1497.
2737	1.64	34.643	2699	27.738	46.5	1.44	35.4	20.42	221.09	109	2.39	1502.
2989	1.58	34.652	2946	27.749	45.8	1.36	34.2	21.58	255.03	123	2.60	1506.
3244	1.55	34.665	3195	27.762	45.2	1.31	32.8	22.74	291.78	138	2.80	1510.
3503	1.53	34.671	3448	27.768	45.2	1.26	32.1	23.91	331.96	160	2.93	1514.
3660	1.53	34.676	3601	27.772	45.2	1.24	31.6	24.61	357.81	167	3.08	1517.
3816	1.52	34.678	3754	27.775	45.4	1.22	31.2	25.32	384.87	206	3.15	1520.
3975	1.52	34.677	3903	27.774	45.9	1.20	31.2	26.05	413.67	218	3.22	1522.
4136	1.53	34.682	4066	27.777	46.1	1.19	30.8	26.79	444.29	185	3.25	1525.

PACIFIC OCEANOGRAPHIC GROUP

DATE 16/ 2/70

REFERENCE NO. 70- 1- 28

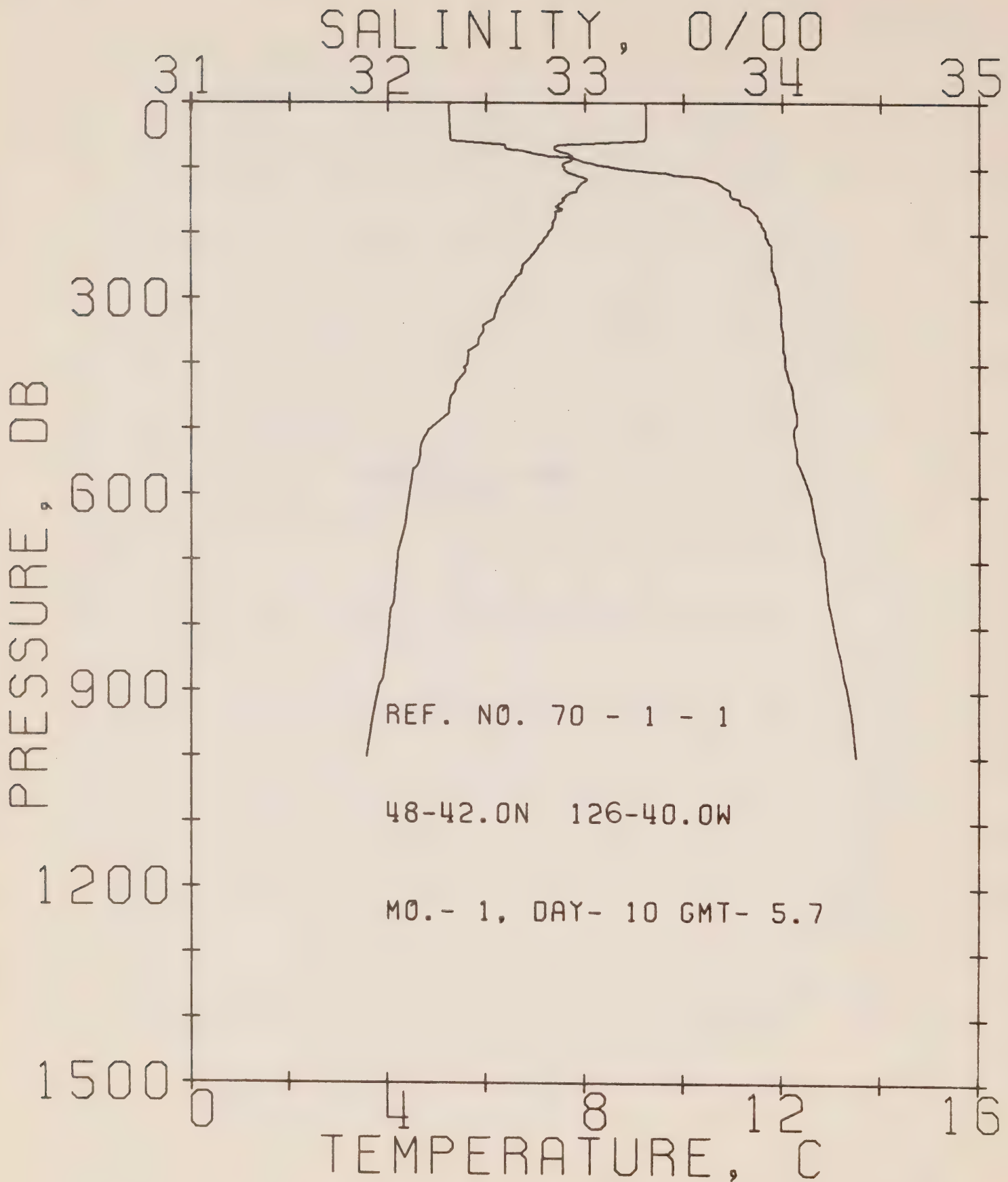
POSITION 50- 0.0N, 145- 0.0W

GMT 19.3

HYDROGRAPHIC CAST DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. FN	V-B PERIOD	OXY	SOUND
0	5.34	32.663	0	25.811	219.5	5.34	219.5	0.00	0.00	65	7.10	1469.
10	5.29	32.659	10	25.814	219.6	5.29	219.2	0.22	0.01	341	7.08	1469.
19	5.32	32.660	19	25.811	220.0	5.32	219.5	0.42	0.04	84	7.11	1470.
28	5.28	32.661	28	25.817	219.5	5.28	219.0	0.62	0.09	61	7.10	1470.
47	5.28	32.661	47	25.817	219.7	5.28	218.9	1.04	0.25	67	7.08	1470.
69	5.24	32.669	69	25.828	218.9	5.23	217.9	1.53	0.54	32	7.08	1470.
92	5.17	32.706	91	25.865	215.6	5.16	214.3	2.01	0.94	9	6.97	1470.
114	4.12	33.306	113	26.453	159.7	4.11	158.5	2.42	1.36	8	4.88	1467.
136	4.12	33.562	135	26.656	140.7	4.11	139.2	2.75	1.78	13	3.69	1468.
158	4.03	33.681	157	26.760	131.0	4.02	129.4	3.05	2.23	18	2.97	1468.
179	3.92	33.739	178	26.817	125.7	3.91	123.9	3.32	2.70	23	2.44	1468.
224	3.75	33.809	222	26.890	119.1	3.73	117.0	3.86	3.81	27	1.65	1468.
268	3.70	33.879	266	26.950	113.7	3.68	111.2	4.38	5.10	30	1.13	1468.
359	3.64	34.008	356	27.059	104.2	3.62	100.9	5.37	8.24	34	0.80	1470.
454	3.58	34.085	450	27.126	98.5	3.55	94.5	6.33	12.21	39	0.64	1471.
553	3.46	34.167	548	27.202	91.9	3.42	87.1	7.27	17.04	39	0.59	1472.
761	3.10	34.306	754	27.347	79.2	3.05	73.3	9.05	28.83	44	0.59	1475.
954	2.85	34.380	945	27.429	72.2	2.79	65.5	10.50	41.55	54	0.58	1477.
1147	2.65	34.430	1135	27.486	67.5	2.57	60.0	11.85	55.91	60	0.55	1479.
1438	2.37	34.493	1422	27.560	61.3	2.27	52.8	13.72	80.51	64	0.68	1483.
1682	2.16	34.537	1663	27.613	56.7	2.05	47.8	15.16	103.42	69	1.02	1486.
1930	1.98	34.575	1907	27.657	52.9	1.85	43.4	16.52	128.39	78	1.36	1489.
2183	1.87	34.601	2155	27.687	50.6	1.72	40.5	17.82	155.72	91	1.65	1493.
2440	1.76	34.619	2408	27.710	48.8	1.59	38.2	19.10	185.87	98	2.01	1497.
2781	1.64	34.641	2742	27.736	46.8	1.44	35.5	20.72	229.14	109	2.42	1502.
3036	1.58	34.650	2992	27.748	46.1	1.36	34.3	21.91	264.27	117	2.69	1506.
3291	1.53	34.664	3241	27.763	45.1	1.28	32.7	23.07	301.67	138	0.00	1511.
3547	1.53	34.669	3491	27.767	45.4	1.25	32.2	24.23	341.99	194	3.01	1515.
3791	1.53	34.671	3641	27.768	45.7	1.24	31.9	24.93	367.85	183	3.12	1518.
3854	1.52	34.673	3791	27.771	45.8	1.21	31.6	25.63	394.94	181	3.20	1520.
4008	1.52	34.675	3941	27.772	46.1	1.20	31.3	26.34	423.27	197	3.23	1523.
4162	1.53	34.679	4091	27.775	46.4	1.19	31.0	27.05	452.90	538	3.32	1526.
4265	1.55	34.678	4191	27.773	47.0	1.20	31.1	27.53	473.50	234	3.27	1527.

RESULTS OF STD CASTS
(P-70-1)



PACIFIC OCEANOGRAPHIC GROUP

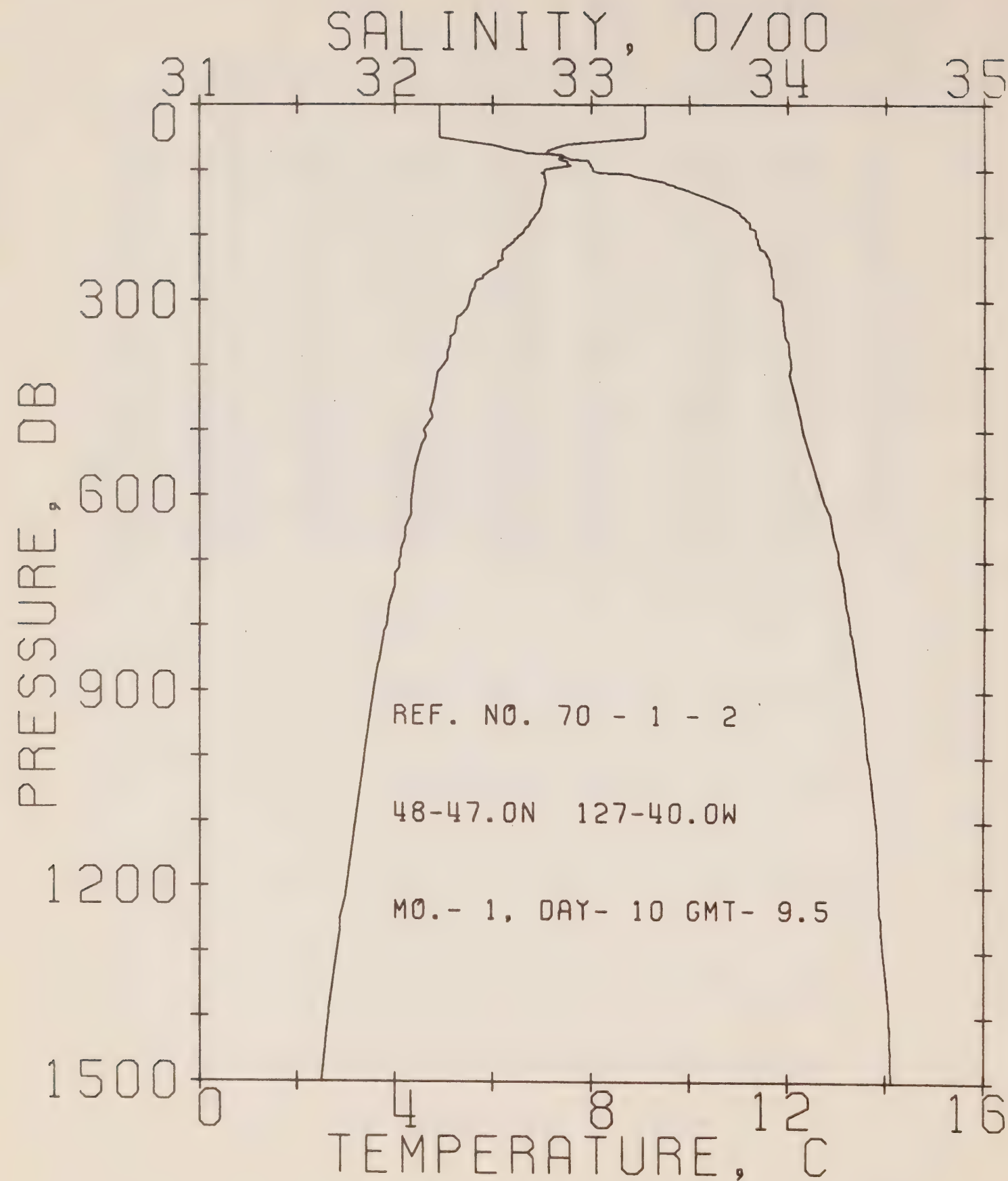
REFERENCE NO. 70- 1- 1

DATE 10/ 1/70

POSITION 48-42.0N, 126-40.0W GMT 5.7

RESULTS OF STP CAST 133 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	9.23	32.32	0	25.01	295.7	0.00	0.00	1484.
10	9.25	32.31	10	25.00	297.1	0.30	0.02	1484.
20	9.25	32.31	20	25.00	297.1	0.59	0.06	1484.
30	9.25	32.32	30	25.00	297.1	0.89	0.14	1485.
50	9.25	32.32	50	25.00	297.2	1.49	0.38	1485.
75	7.49	32.71	75	25.57	243.6	2.16	0.81	1479.
100	7.59	33.16	99	25.91	211.9	2.73	1.31	1481.
125	7.92	33.69	124	26.28	177.3	3.21	1.86	1483.
150	7.57	33.79	149	26.41	165.2	3.64	2.46	1482.
175	7.41	33.88	174	26.50	156.7	4.04	3.13	1482.
200	7.27	33.92	199	26.55	152.3	4.43	3.86	1482.
225	7.03	33.95	223	26.61	147.1	4.80	4.67	1481.
250	6.75	33.95	248	26.65	143.7	5.17	5.56	1481.
300	6.32	33.99	298	26.73	135.8	5.87	7.51	1480.
400	5.62	34.02	397	26.85	126.0	7.17	12.17	1479.
500	4.89	34.06	496	26.97	114.9	8.38	17.68	1477.
600	4.46	34.15	595	27.08	104.8	9.48	23.85	1477.
800	4.04	34.26	793	27.22	93.0	11.45	37.88	1479.
1000	3.59	34.38	991	27.35	80.9	13.18	53.73	1481.



PACIFIC OCEANOGRAPHIC GROUP

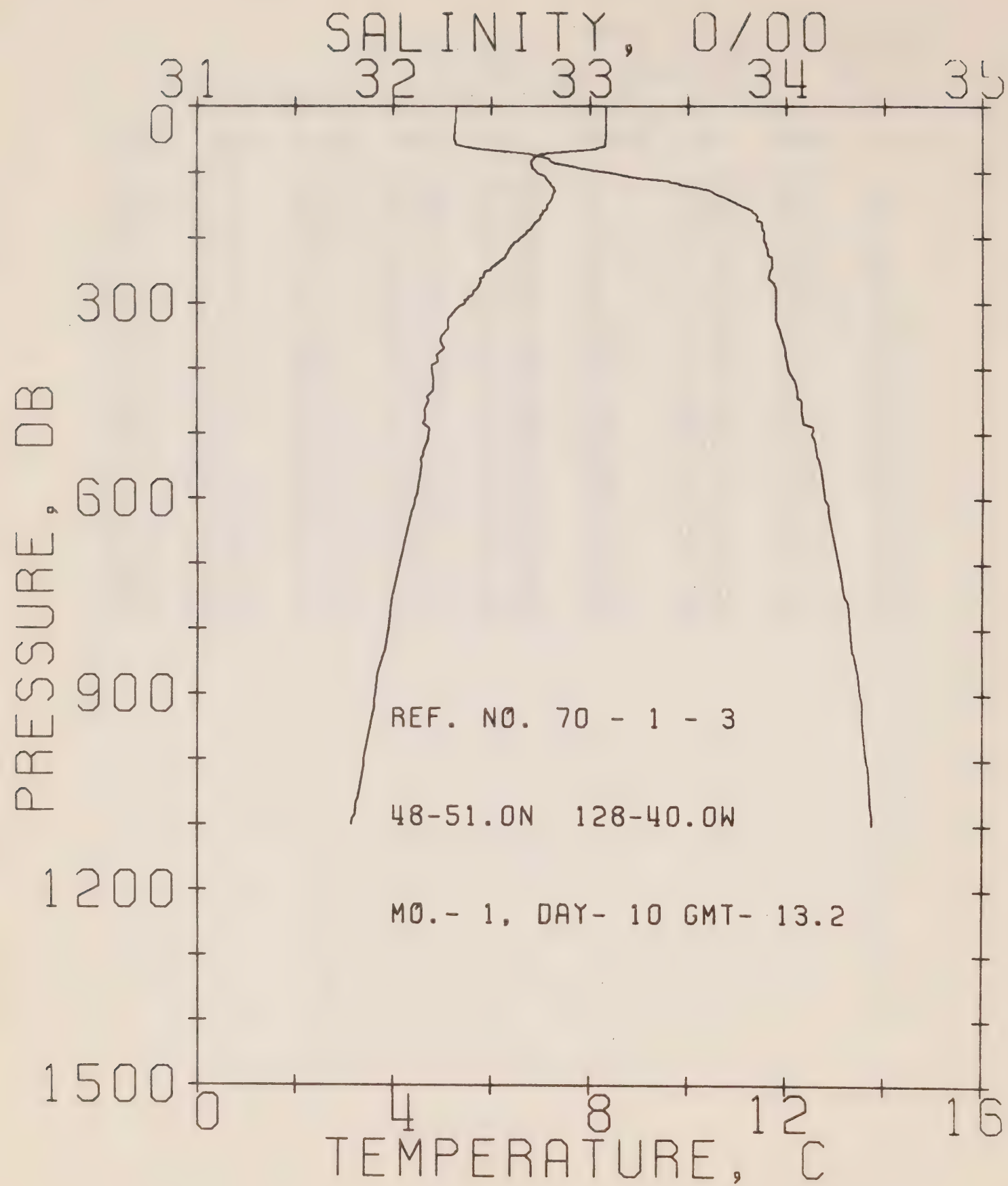
REFERENCE NO. 70- 1- 2

DATE 10/ 1/70

POSITION 48-47.0N, 127-40.0W GMT 9.5

RESULTS OF STP CAST 121 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	9.10	32.23	0	24.96	300.4	0.00	0.00	1484.
10	9.10	32.23	10	24.96	300.9	0.30	0.02	1484.
20	9.11	32.23	20	24.95	301.1	0.60	0.06	1484.
30	9.11	32.23	30	24.95	301.4	0.90	0.14	1484.
50	9.08	32.23	50	24.96	301.3	1.51	0.38	1484.
75	7.15	32.73	75	25.63	237.5	2.16	0.80	1478.
100	7.07	33.01	99	25.86	215.6	2.73	1.30	1478.
125	7.08	33.43	124	26.19	185.0	3.22	1.87	1479.
150	7.01	33.66	149	26.38	167.6	3.66	2.48	1480.
175	6.84	33.79	174	26.51	155.7	4.06	3.15	1480.
200	6.59	33.84	199	26.58	149.1	4.44	3.87	1479.
225	6.22	33.89	223	26.67	141.0	4.81	4.66	1478.
250	6.10	33.92	248	26.71	137.5	5.16	5.51	1478.
300	5.54	33.96	298	26.81	128.3	5.82	7.36	1477.
400	5.02	34.02	397	26.92	118.7	7.05	11.74	1476.
500	4.62	34.08	496	27.01	110.8	8.20	17.01	1476.
600	4.37	34.18	595	27.11	101.5	9.26	22.95	1477.
800	3.86	34.32	793	27.28	86.9	11.13	36.24	1478.
1000	3.40	34.41	991	27.40	76.5	12.75	51.07	1480.
1200	3.03	34.47	1188	27.48	69.3	14.20	67.23	1482.
1500	2.50	34.53	1484	27.57	60.4	16.13	93.74	1484.



PACIFIC OCEANOGRAPHIC GROUP

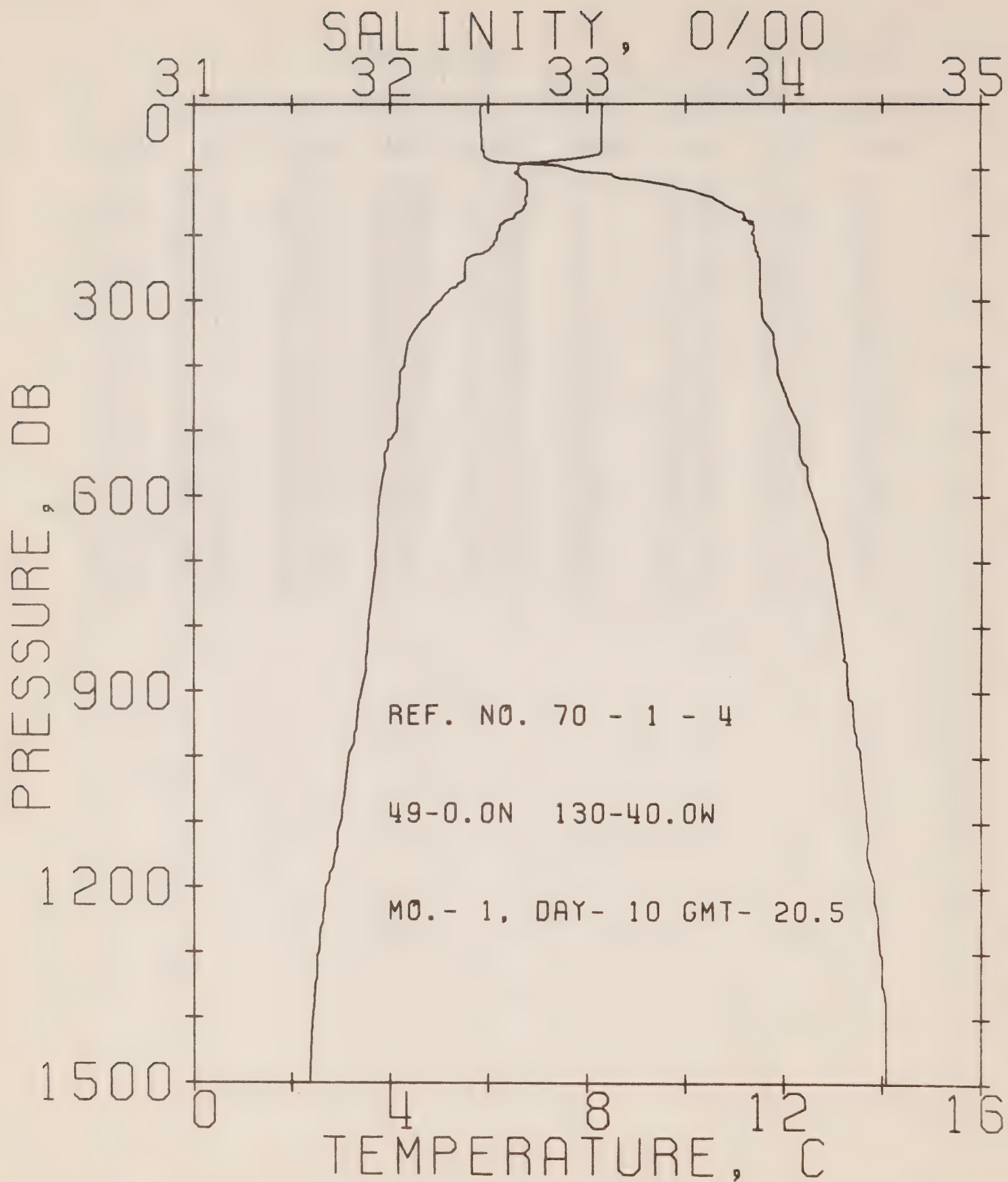
REFERENCE NO. 70- 1- 3

DATE 10/ 1/70

POSITION 48-51.0N, 128-40.0W GMT 13.2

RESULTS OF STP CAST 131 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.35	32.32	0	25.14	282.9	0.00	0.00	1481.
10	8.35	32.32	10	25.14	283.4	0.28	0.01	1481.
20	8.35	32.32	20	25.14	283.7	0.57	0.06	1481.
30	8.35	32.31	30	25.14	284.0	0.85	0.13	1481.
50	8.35	32.31	50	25.13	284.6	1.42	0.36	1482.
75	6.94	32.73	75	25.66	234.7	2.09	0.79	1477.
100	6.92	33.08	99	25.94	208.3	2.65	1.28	1478.
125	7.29	33.57	124	26.27	177.6	3.13	1.84	1480.
150	7.15	33.76	149	26.44	161.5	3.56	2.43	1480.
175	6.96	33.86	174	26.54	152.3	3.95	3.07	1480.
200	6.63	33.89	199	26.61	145.9	4.32	3.78	1479.
225	6.35	33.91	223	26.67	141.1	4.67	4.56	1479.
250	6.01	33.92	248	26.72	136.4	5.02	5.39	1478.
300	5.49	33.95	298	26.81	128.4	5.68	7.24	1477.
400	4.80	34.01	397	26.94	116.7	6.90	11.59	1475.
500	4.75	34.13	496	27.04	108.1	8.02	16.73	1477.
600	4.49	34.20	595	27.12	101.1	9.06	22.56	1478.
800	3.93	34.33	793	27.28	86.9	10.93	35.80	1479.
1000	3.43	34.41	991	27.39	76.9	12.56	50.71	1480.



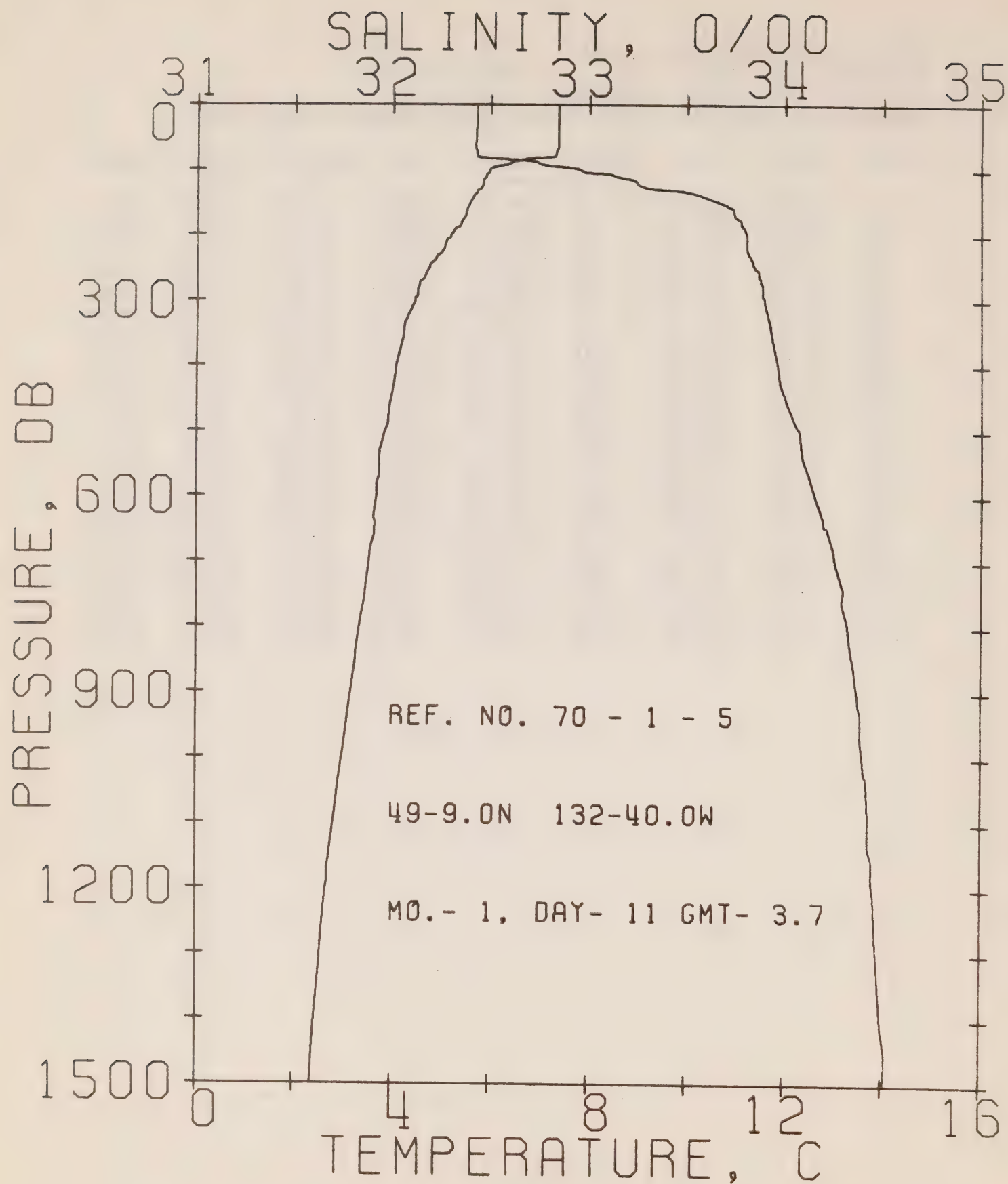
PACIFIC OCEANOGRAPHIC GROUP

REFERENCE NO. 70- 1- 4 DATE 10/ 1/70

POSITION 49- 0.0N, 130-40.0W GMT 20.5

RESULTS OF STP CAST 149 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.33	32.47	0	25.26	271.4	0.00	0.00	1481.
10	8.32	32.46	10	25.26	272.4	0.27	0.01	1481.
20	8.32	32.46	20	25.26	272.4	0.54	0.06	1481.
30	8.32	32.46	30	25.26	272.4	0.82	0.12	1481.
50	8.31	32.47	50	25.26	272.3	1.36	0.35	1482.
75	8.29	32.48	75	25.27	271.6	2.04	0.78	1482.
100	6.62	32.92	99	25.86	216.4	2.66	1.33	1476.
125	6.80	33.42	124	26.22	181.8	3.16	1.90	1478.
150	6.77	33.68	149	26.43	162.6	3.58	2.49	1479.
175	6.54	33.81	174	26.56	150.5	3.98	3.14	1479.
200	6.20	33.84	199	26.63	144.1	4.34	3.83	1478.
225	5.98	33.86	223	26.67	140.2	4.69	4.61	1477.
250	5.54	33.88	248	26.74	133.7	5.03	5.42	1476.
300	5.07	33.89	298	26.81	128.0	5.69	7.27	1475.
400	4.31	33.97	397	26.96	114.4	6.89	11.53	1473.
500	4.15	34.08	496	27.06	105.4	7.99	16.56	1474.
600	3.81	34.15	595	27.15	97.6	9.00	22.25	1475.
800	3.57	34.29	793	27.29	85.7	10.82	35.19	1477.
1000	3.18	34.39	991	27.40	75.4	12.46	50.14	1479.
1200	2.74	34.46	1188	27.50	66.6	13.89	66.22	1480.
1500	2.36	34.52	1484	27.58	59.5	15.75	91.71	1484.



PACIFIC OCEANOGRAPHIC GROUP

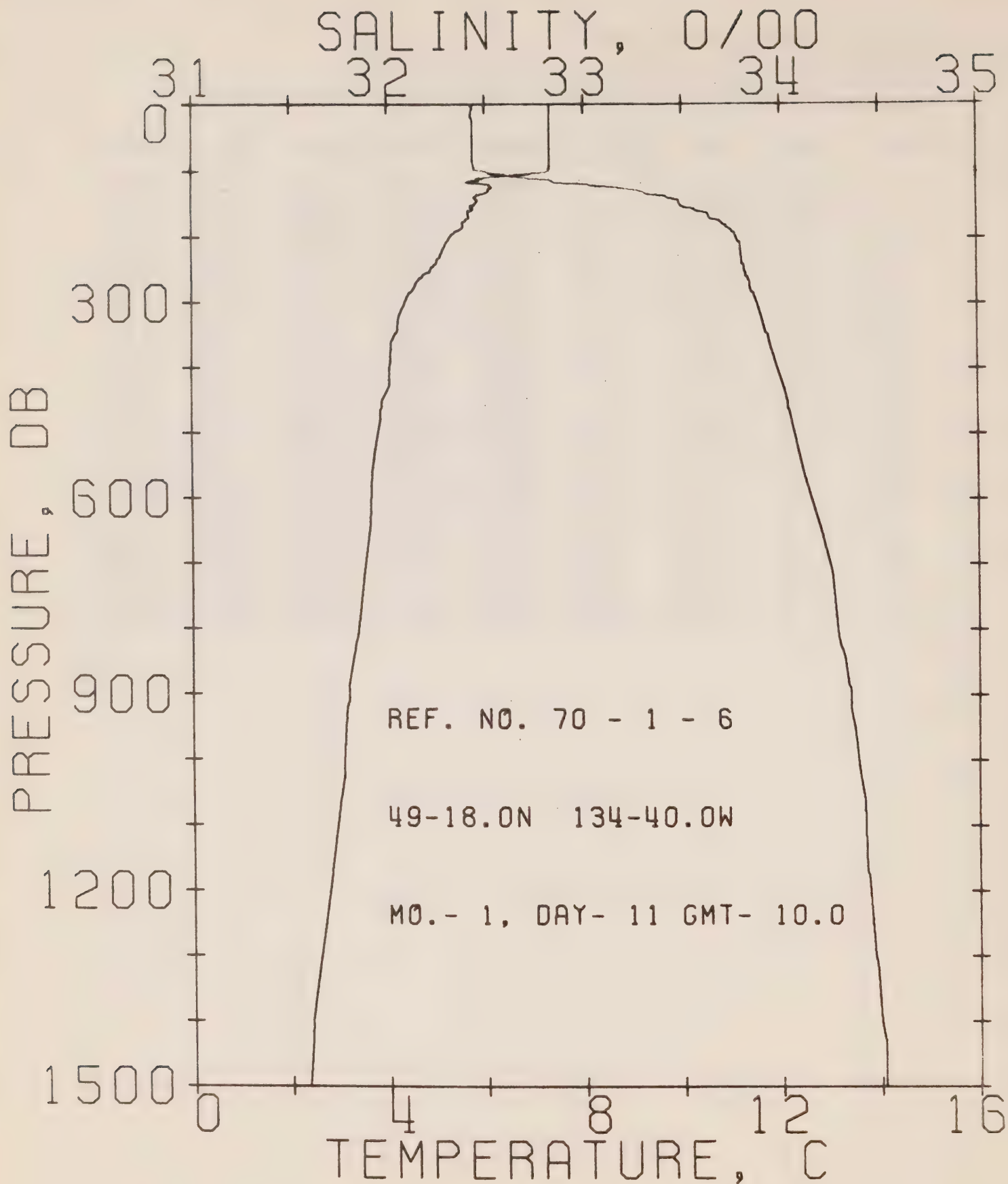
REFERENCE NO. 70- 1- 5

DATE 11/ 1/70

POSITION 49- 9.0N, 132-40.0W GMT 3.7

RESULTS OF STP CAST 108 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.39	32.43	0	25.36	261.6	0.00	0.00	1477.
10	7.39	32.43	10	25.36	262.1	0.26	0.01	1477.
20	7.39	32.43	20	25.36	262.4	0.52	0.05	1478.
30	7.39	32.43	30	25.36	262.6	0.79	0.12	1478.
50	7.39	32.42	50	25.36	263.1	1.31	0.33	1478.
75	7.35	32.43	75	25.37	262.4	1.97	0.75	1478.
100	6.00	32.96	99	25.96	206.2	2.56	1.27	1474.
125	5.85	33.27	124	26.23	181.2	3.03	1.82	1474.
150	5.62	33.67	149	26.57	149.2	3.44	2.39	1474.
175	5.48	33.77	174	26.66	140.6	3.80	2.98	1474.
200	5.22	33.81	199	26.73	134.5	4.14	3.64	1474.
225	5.05	33.81	223	26.75	132.5	4.48	4.36	1473.
250	4.77	33.85	248	26.81	127.0	4.80	5.14	1473.
300	4.48	33.90	298	26.88	120.6	5.42	6.87	1472.
400	4.10	33.97	397	26.98	112.2	6.58	11.00	1472.
500	3.88	34.08	496	27.08	102.8	7.66	15.96	1473.
600	3.70	34.16	595	27.17	95.5	8.65	21.52	1474.
800	3.36	34.32	793	27.33	81.0	10.40	33.97	1476.
1000	3.02	34.40	990	27.42	72.9	11.94	48.00	1478.
1200	2.70	34.45	1188	27.49	66.7	13.33	63.55	1480.
1500	2.37	34.51	1484	27.57	60.2	15.21	89.46	1484.



PACIFIC OCEANOGRAPHIC GROUP

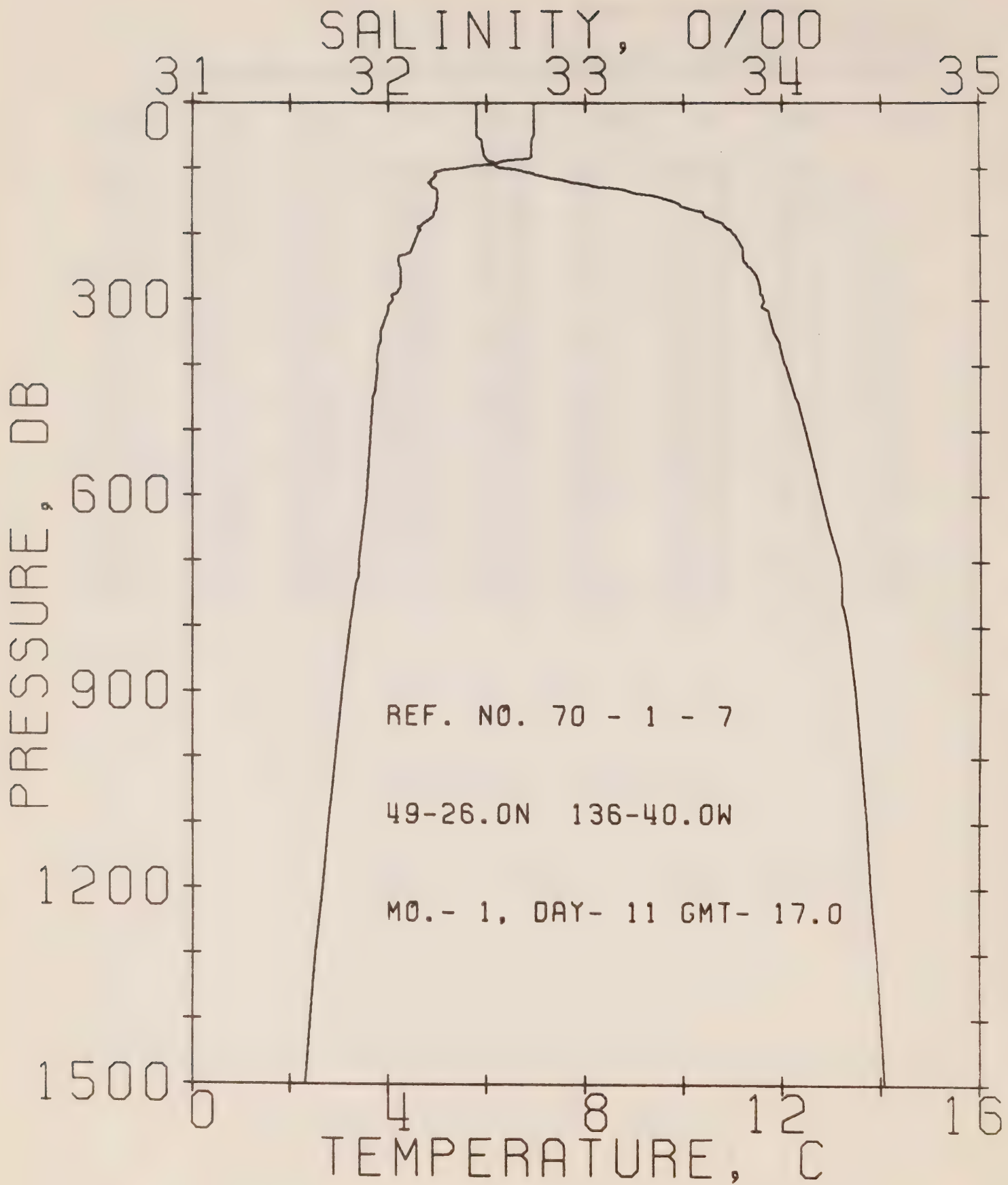
REFERENCE NO. 70- 1- 6

DATE 11/ 1/70

POSITION 49-18.0N, 134-40.0W GMT 10.0

RESULTS OF STP CAST 119 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.35	32.44	0	25.38	260.3	0.00	0.00	1477.
10	7.33	32.43	10	25.37	261.0	0.26	0.01	1477.
20	7.33	32.43	20	25.37	261.4	0.52	0.05	1477.
30	7.33	32.44	30	25.38	260.8	0.78	0.12	1477.
50	7.33	32.44	50	25.38	261.1	1.30	0.33	1478.
75	7.34	32.44	75	25.38	261.5	1.96	0.75	1478.
100	7.27	32.51	99	25.45	255.5	2.61	1.33	1478.
125	6.13	33.21	124	26.14	189.5	3.16	1.96	1475.
150	5.83	33.50	149	26.41	164.4	3.59	2.56	1475.
175	5.62	33.70	174	26.59	147.2	3.98	3.20	1475.
200	5.31	33.78	199	26.70	137.6	4.33	3.88	1474.
225	5.14	33.81	223	26.74	134.1	4.67	4.61	1474.
250	4.91	33.82	248	26.77	130.6	5.00	5.41	1473.
300	4.38	33.89	298	26.88	120.4	5.63	7.16	1472.
400	4.06	33.99	397	27.00	110.3	6.78	11.26	1472.
500	3.83	34.07	496	27.09	102.3	7.84	16.11	1473.
600	3.68	34.16	595	27.17	95.3	8.83	21.65	1474.
800	3.41	34.29	793	27.30	84.3	10.60	34.26	1476.
1000	3.10	34.39	990	27.41	74.7	12.17	48.67	1479.
1200	2.79	34.44	1188	27.48	68.3	13.60	64.66	1481.
1500	2.34	34.52	1484	27.58	59.2	15.50	90.64	1484.



PACIFIC OCEANOGRAPHIC GROUP

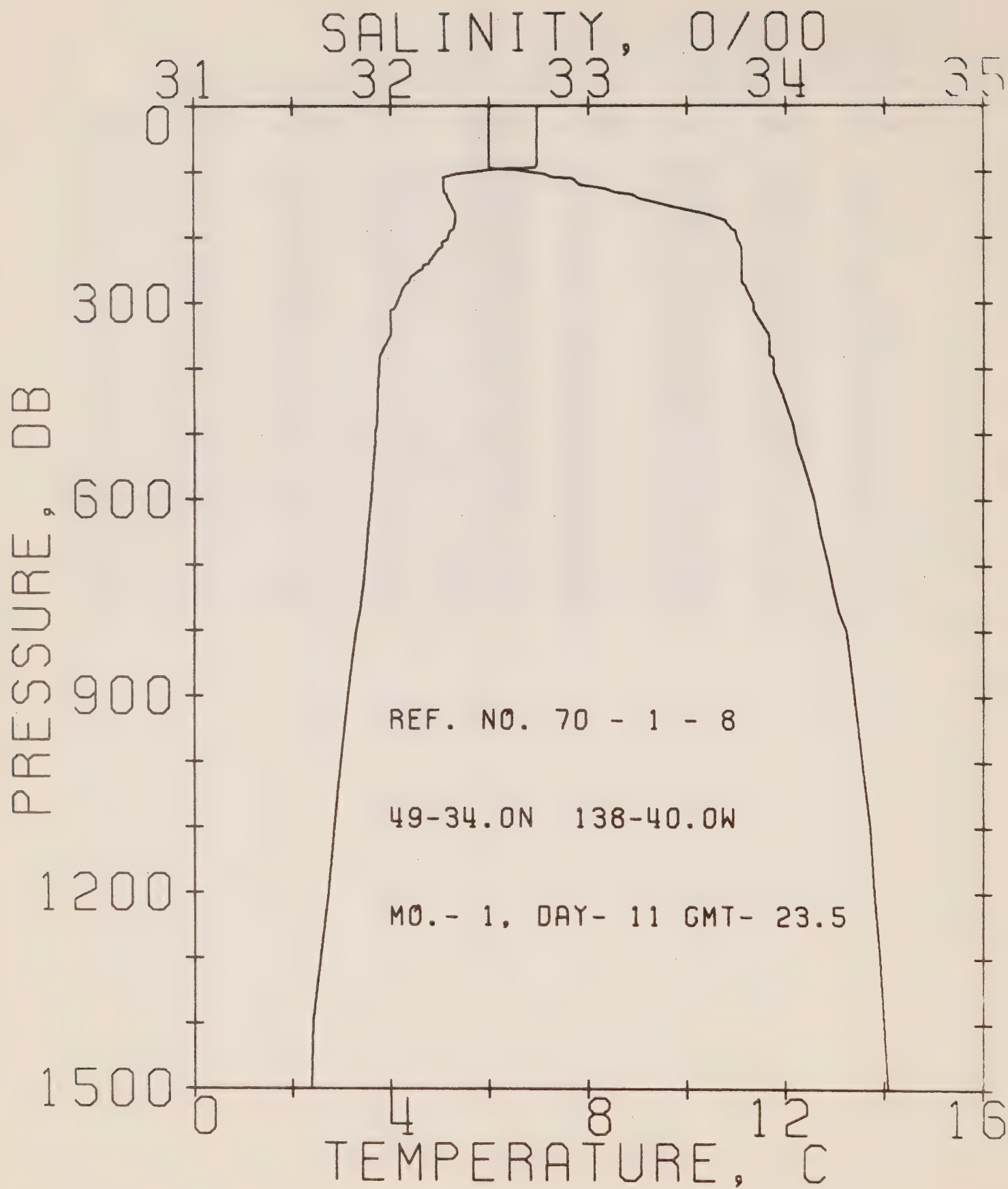
REFERENCE NO. 70- 1- 7

DATE 11/ 1/70

POSITION 49-26.0N, 136-40.0W GMT 17.0

RESULTS OF STP CAST 111 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.97	32.46	0	25.44	253.9	0.00	0.00	1476.
10	6.97	32.45	10	25.44	255.1	0.25	0.01	1476.
20	6.97	32.45	20	25.44	255.2	0.51	0.05	1476.
30	6.97	32.45	30	25.44	255.3	0.77	0.12	1476.
50	6.97	32.45	50	25.44	255.6	1.28	0.33	1476.
75	6.92	32.49	75	25.47	252.4	1.91	0.73	1477.
100	5.25	32.63	99	25.79	222.1	2.52	1.27	1471.
125	4.87	33.03	124	26.15	188.6	3.03	1.85	1470.
150	5.02	33.45	149	26.47	158.6	3.46	2.45	1471.
175	4.89	33.63	174	26.62	144.2	3.84	3.08	1472.
200	4.61	33.76	199	26.76	131.5	4.18	3.73	1471.
225	4.48	33.80	223	26.80	127.4	4.50	4.43	1471.
250	4.24	33.83	248	26.85	122.6	4.81	5.18	1470.
300	4.10	33.91	298	26.93	115.9	5.41	6.85	1471.
400	3.79	34.02	397	27.05	105.4	6.51	10.78	1471.
500	3.66	34.12	496	27.14	97.3	7.52	15.41	1472.
600	3.57	34.20	595	27.21	91.1	8.46	20.67	1474.
800	3.24	34.33	793	27.35	79.3	10.16	32.72	1476.
1000	2.94	34.40	990	27.43	72.1	11.67	46.51	1478.
1200	2.67	34.45	1188	27.50	66.6	13.05	61.99	1480.
1500	2.32	34.52	1484	27.58	59.1	14.92	87.71	1484.



PACIFIC OCEANOGRAPHIC GROUP

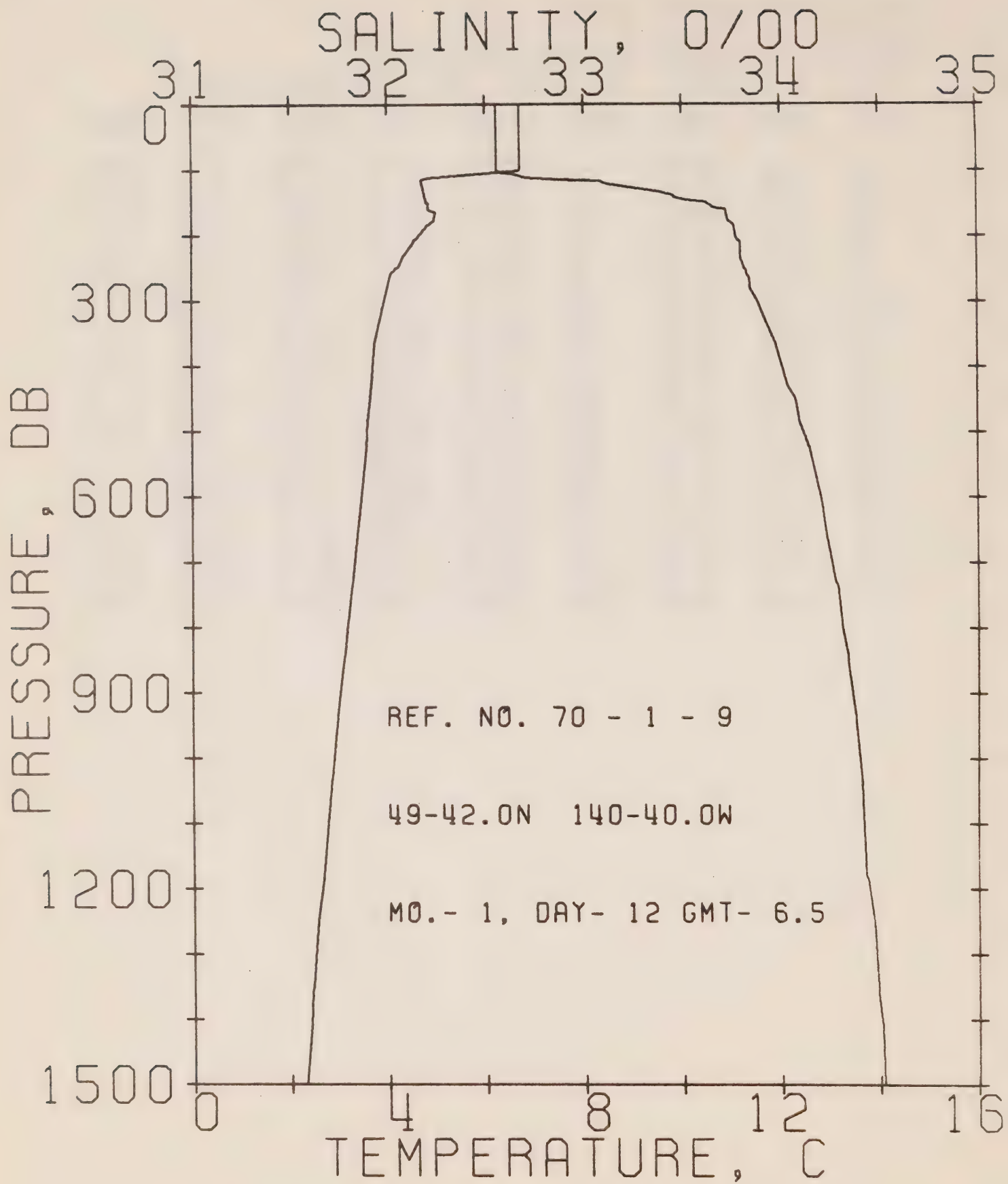
REFERENCE NO. 70- 1- 8

DATE 11/ 1/70

POSITION 49-34.0N, 138-40.0W GMT 23.5

RESULTS OF STP CAST 67 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.03	32.51	0	25.48	251.0	0.00	0.00	1476.
10	6.99	32.50	10	25.47	251.6	0.25	0.01	1476.
20	6.99	32.50	20	25.47	251.7	0.50	0.05	1476.
30	6.98	32.50	30	25.47	251.8	0.75	0.12	1476.
50	6.98	32.50	50	25.47	252.0	1.26	0.32	1476.
75	6.97	32.50	75	25.48	252.2	1.89	0.72	1477.
100	5.78	32.69	99	25.77	223.9	2.51	1.28	1473.
125	5.08	33.06	124	26.15	188.7	3.02	1.85	1471.
150	5.22	33.37	149	26.38	167.0	3.46	2.47	1472.
175	5.32	33.69	174	26.62	144.3	3.85	3.12	1473.
200	5.19	33.76	199	26.69	138.3	4.20	3.79	1473.
225	4.93	33.78	223	26.74	133.8	4.54	4.52	1473.
250	4.66	33.78	248	26.77	131.0	4.87	5.33	1472.
300	4.16	33.84	298	26.87	121.8	5.50	7.09	1471.
400	3.78	33.94	397	26.99	111.0	6.66	11.20	1471.
500	3.70	34.05	496	27.08	102.9	7.73	16.10	1472.
600	3.61	34.15	595	27.17	95.3	8.72	21.65	1474.
800	3.32	34.30	793	27.32	81.9	10.51	34.37	1476.
1000	3.00	34.39	990	27.42	73.5	12.06	48.56	1478.
1200	2.74	34.45	1188	27.49	67.4	13.46	64.24	1480.
1500	2.37	34.52	1484	27.58	59.7	15.35	90.14	1484.



PACIFIC OCEANOGRAPHIC GROUP

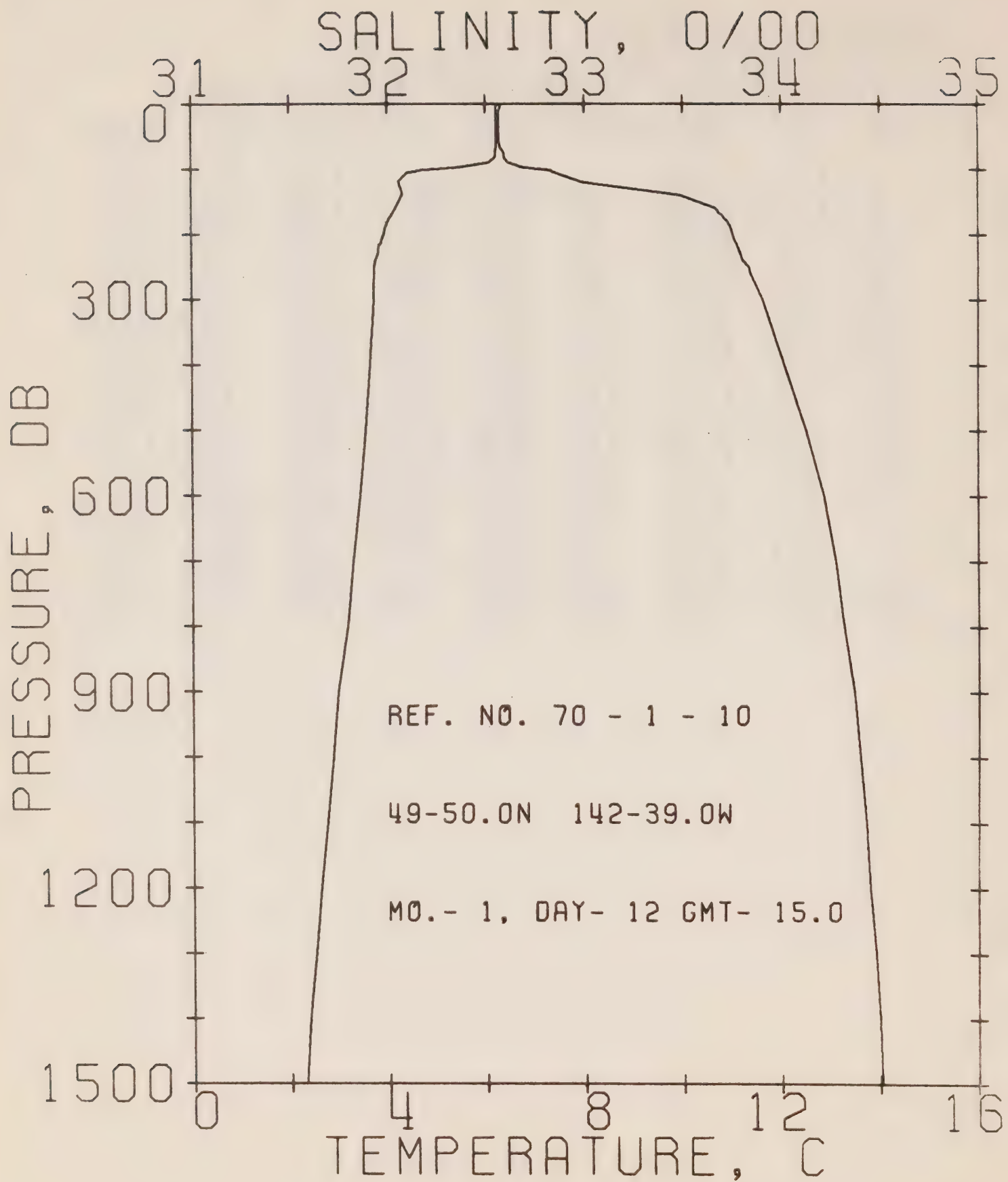
REFERENCE NO. 70- 1- 9

DATE 12/ 1/70

POSITION 49-42.0N, 140-40.0W GMT 6.5

RESULTS OF STP CAST 57 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.72	32.56	0	25.56	243.3	0.00	0.00	1475.
10	6.72	32.56	10	25.56	243.7	0.24	0.01	1475.
20	6.72	32.56	20	25.56	243.8	0.49	0.05	1475.
30	6.72	32.56	30	25.56	244.0	0.73	0.11	1475.
50	6.72	32.56	50	25.56	244.2	1.22	0.31	1476.
75	6.72	32.56	75	25.56	244.5	1.83	0.70	1476.
100	6.72	32.56	99	25.56	244.8	2.44	1.25	1476.
125	4.72	33.21	124	26.30	173.6	2.96	1.83	1470.
150	4.82	33.63	149	26.63	143.0	3.35	2.38	1471.
175	4.98	33.74	174	26.70	137.0	3.70	2.96	1472.
200	4.67	33.78	199	26.76	130.8	4.03	3.60	1471.
225	4.41	33.80	223	26.81	126.6	4.35	4.29	1471.
250	4.17	33.82	248	26.85	122.8	4.67	5.05	1470.
300	3.96	33.89	298	26.93	116.0	5.26	6.72	1470.
400	3.71	34.01	397	27.05	105.0	6.36	10.63	1471.
500	3.59	34.12	496	27.14	96.7	7.37	15.24	1472.
600	3.48	34.20	595	27.23	89.7	8.30	20.43	1473.
800	3.19	34.31	793	27.34	80.0	9.99	32.48	1476.
1000	2.90	34.40	990	27.43	71.7	11.50	46.28	1478.
1200	2.65	34.44	1188	27.49	66.8	12.89	61.82	1480.
1500	2.31	34.52	1484	27.58	58.9	14.75	87.42	1484.



PACIFIC OCEANOGRAPHIC GROUP

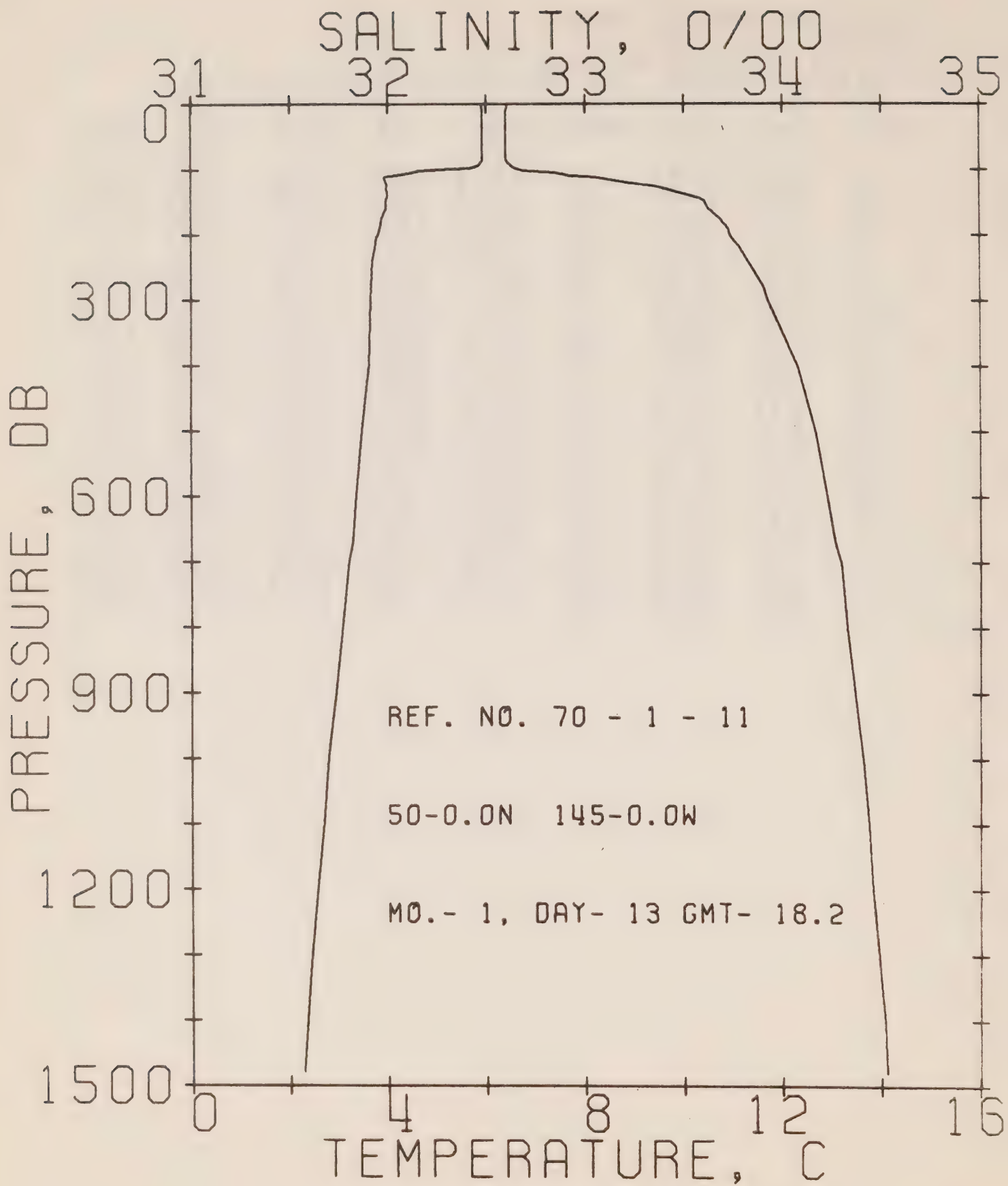
REFERENCE NO. 70- 1- 10

DATE 12/ 1/70

POSITION 49-50.0N, 142-39.0W GMT 15.0

RESULTS OF STP CAST 42 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.25	32.58	0	25.63	236.1	0.00	0.00	1473.
10	6.24	32.57	10	25.63	237.1	0.24	0.01	1473.
20	6.24	32.57	20	25.63	237.2	0.47	0.05	1473.
30	6.24	32.57	30	25.63	237.4	0.71	0.11	1473.
50	6.24	32.57	50	25.63	237.6	1.19	0.30	1474.
75	6.23	32.60	75	25.65	235.6	1.78	0.68	1474.
100	5.08	32.76	99	25.91	210.9	2.35	1.19	1470.
125	4.25	33.10	124	26.27	176.6	2.83	1.74	1467.
150	4.26	33.57	149	26.65	141.4	3.22	2.28	1468.
175	4.08	33.71	174	26.78	129.3	3.56	2.84	1468.
200	3.95	33.76	199	26.83	124.7	3.87	3.44	1468.
225	3.83	33.79	223	26.86	121.3	4.18	4.11	1468.
250	3.75	33.84	248	26.91	117.3	4.48	4.83	1468.
300	3.73	33.91	298	26.97	112.1	5.05	6.44	1469.
400	3.65	34.02	397	27.06	103.8	6.13	10.27	1471.
500	3.56	34.13	496	27.16	95.5	7.13	14.82	1472.
600	3.44	34.22	595	27.24	88.3	8.05	19.95	1473.
800	3.17	34.32	793	27.35	79.3	9.72	31.81	1476.
1000	2.88	34.40	990	27.44	71.4	11.21	45.50	1478.
1200	2.62	34.45	1188	27.50	66.0	12.59	60.84	1480.
1500	2.31	34.51	1484	27.57	59.6	14.45	86.51	1484.



PACIFIC OCEANOGRAPHIC GROUP

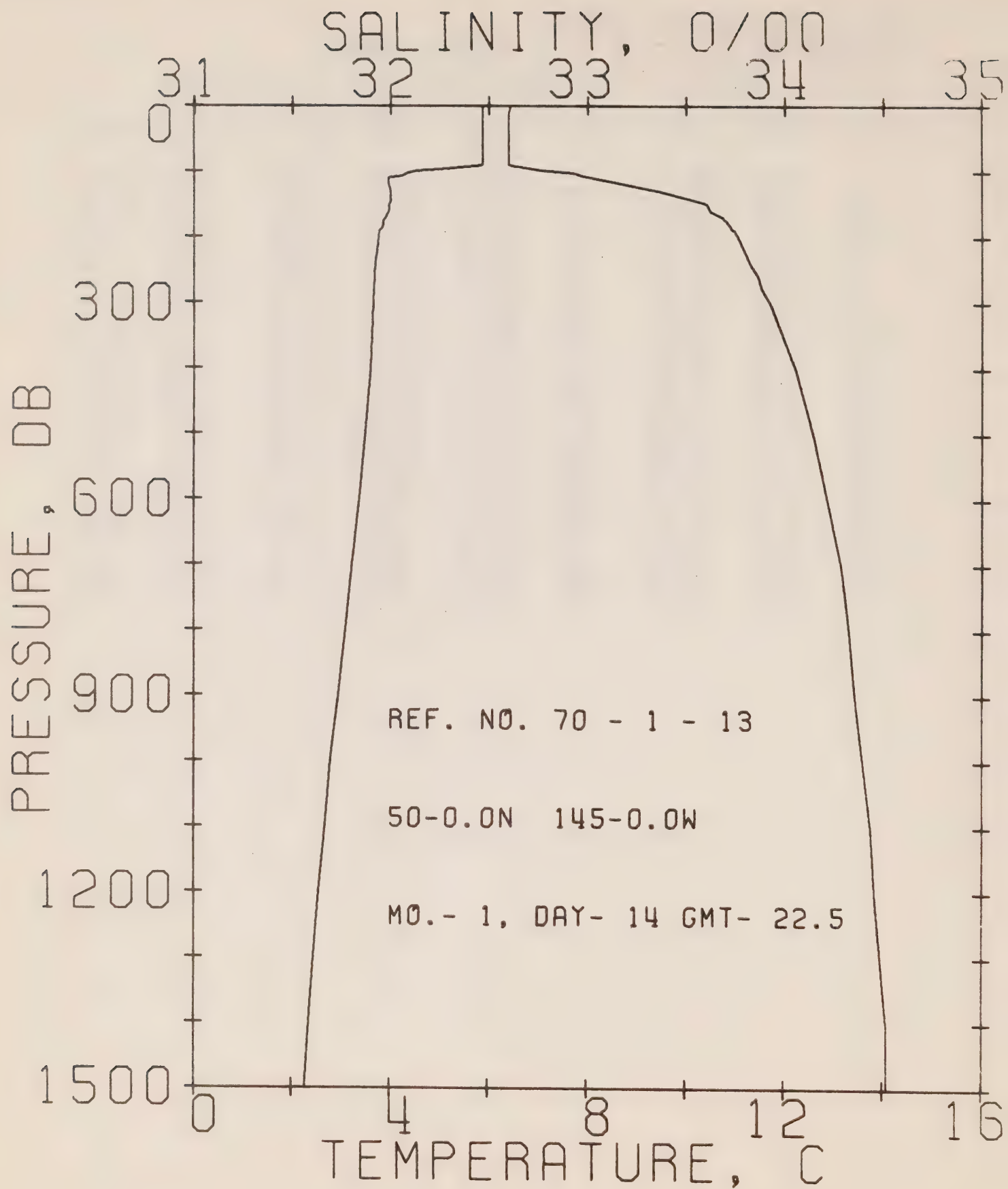
REFERENCE NO. 70- 1- 11

DATE 13/ 1/70

POSITION 50- 0.0N, 145- 0.0W GMT 18.2

RESULTS OF STP CAST 45 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.91	32.61	0	25.70	229.9	0.00	0.00	1472.
10	5.93	32.60	10	25.69	231.2	0.23	0.01	1472.
20	5.93	32.60	20	25.69	231.3	0.46	0.05	1472.
30	5.93	32.60	30	25.69	231.5	0.69	0.11	1472.
50	5.93	32.60	50	25.69	231.7	1.16	0.29	1472.
75	5.93	32.60	75	25.69	231.9	1.74	0.66	1473.
100	5.20	32.67	99	25.83	219.0	2.31	1.18	1470.
125	3.99	33.32	124	26.47	157.4	2.77	1.70	1467.
150	3.98	33.61	149	26.71	135.6	3.13	2.20	1467.
175	3.89	33.68	174	26.77	129.6	3.46	2.76	1467.
200	3.82	33.74	199	26.82	124.9	3.78	3.36	1468.
225	3.73	33.80	223	26.88	119.8	4.09	4.02	1468.
250	3.69	33.85	248	26.92	115.9	4.38	4.74	1468.
300	3.66	33.93	298	26.99	109.9	4.94	6.31	1469.
400	3.61	34.08	397	27.11	99.0	5.99	10.01	1470.
500	3.47	34.17	496	27.20	91.6	6.94	14.36	1472.
600	3.35	34.23	595	27.26	86.5	7.83	19.34	1473.
800	3.07	34.33	793	27.36	77.5	9.46	30.93	1475.
1000	2.79	34.41	990	27.45	69.8	10.93	44.42	1477.
1200	2.56	34.46	1188	27.51	64.6	12.28	59.43	1480.



PACIFIC OCEANOGRAPHIC GROUP

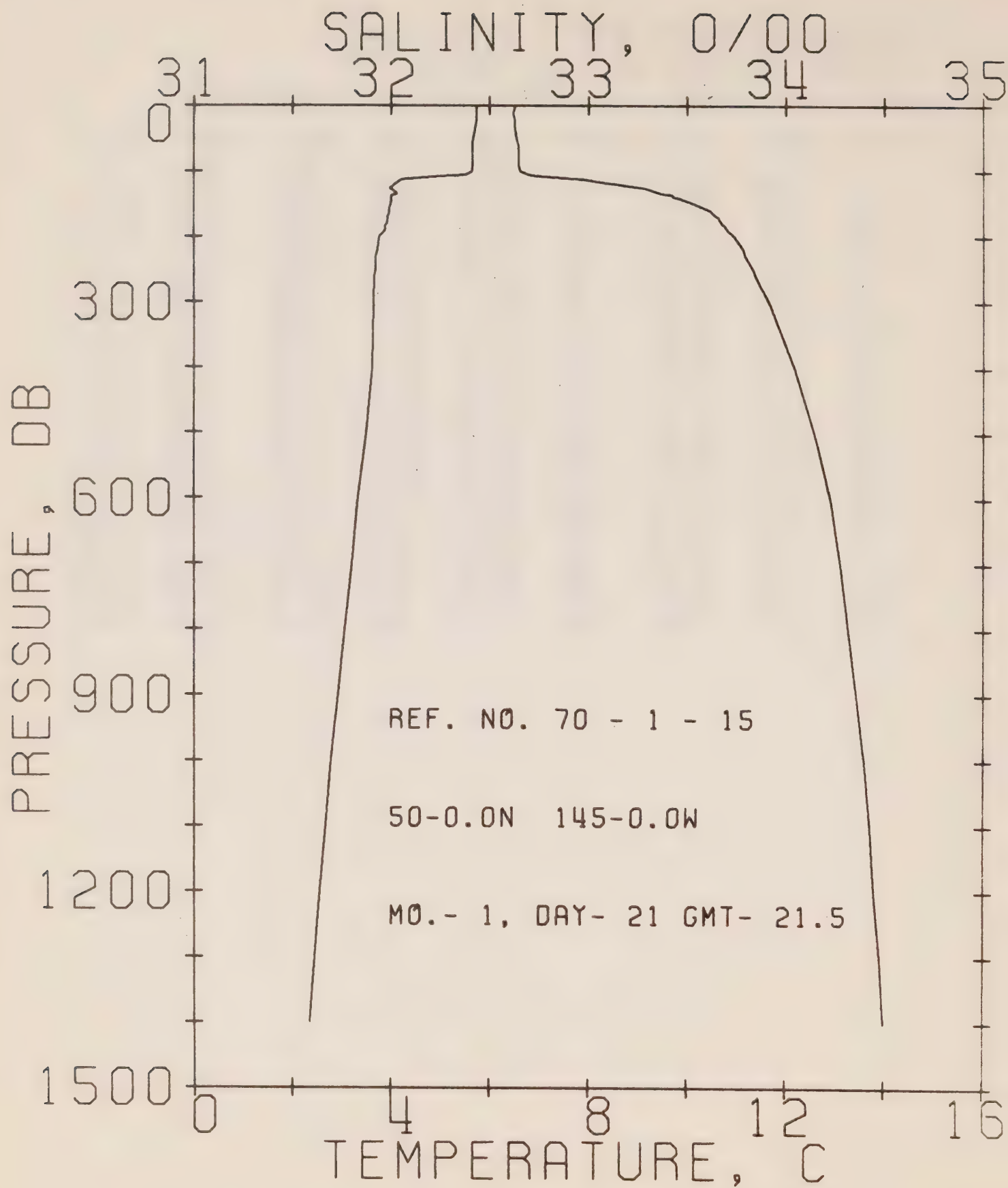
REFERENCE NO. 70- 1- 13

DATE 14/ 1/70

POSITION 50- 0.0N, 145- 0.0W GMT 22.5

RESULTS OF STP CAST 41 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.88	32.61	0	25.70	229.5	0.00	0.00	1471.
10	5.88	32.60	10	25.69	230.7	0.23	0.01	1472.
20	5.88	32.60	20	25.69	230.8	0.46	0.05	1472.
30	5.88	32.60	30	25.69	230.9	0.69	0.11	1472.
50	5.88	32.60	50	25.69	231.1	1.15	0.29	1472.
75	5.88	32.60	75	25.69	231.4	1.73	0.66	1473.
100	4.47	32.83	99	26.04	198.9	2.30	1.16	1468.
125	3.98	33.28	124	26.44	160.6	2.74	1.67	1466.
150	3.99	33.61	149	26.70	136.1	3.11	2.18	1467.
175	3.87	33.70	174	26.79	127.8	3.44	2.73	1467.
200	3.76	33.77	199	26.85	122.2	3.75	3.33	1467.
225	3.72	33.81	223	26.89	119.1	4.05	3.98	1468.
250	3.69	33.85	248	26.92	115.9	4.35	4.69	1468.
300	3.66	33.93	298	26.99	110.0	4.91	6.28	1469.
400	3.60	34.06	397	27.10	100.4	5.96	10.00	1470.
500	3.49	34.15	496	27.18	93.2	6.93	14.43	1472.
600	3.37	34.22	595	27.25	87.5	7.83	19.48	1473.
800	3.10	34.33	793	27.36	77.7	9.48	31.14	1475.
1000	2.80	34.40	990	27.44	70.6	10.96	44.76	1477.
1200	2.56	34.46	1188	27.51	64.6	12.31	59.82	1480.
1500	2.27	34.52	1483	27.59	58.4	14.13	84.84	1483.



PACIFIC OCEANOGRAPHIC GROUP

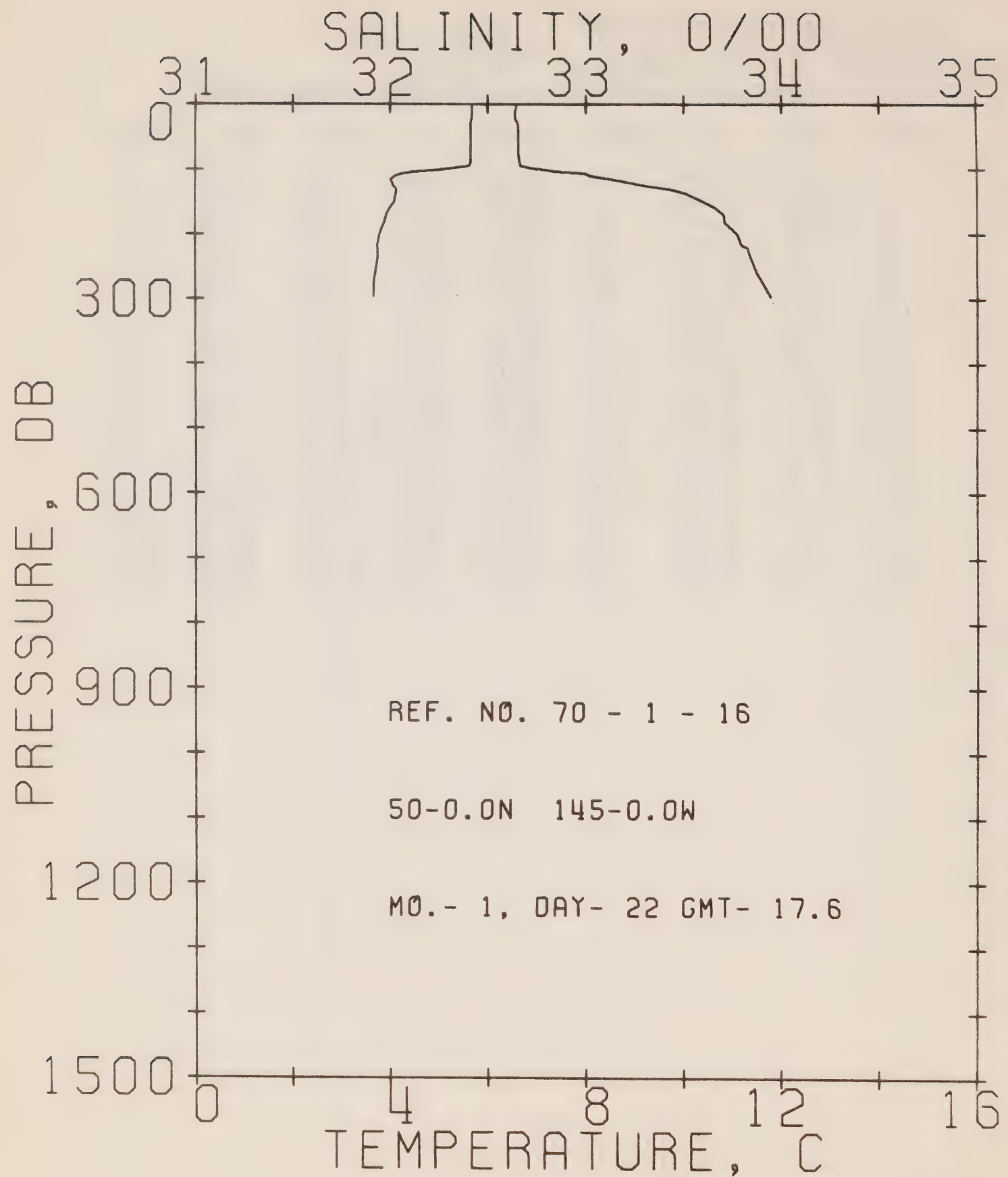
REFERENCE NO. 70- 1- 15

DATE 21/ 1/70

POSITION 50- 0.0N, 145- 0.0W GMT 21.5

RESULTS OF STP CAST 43 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.74	32.63	0	25.73	226.4	0.00	0.00	1471.
10	5.74	32.62	10	25.73	227.5	0.23	0.01	1471.
20	5.74	32.63	20	25.73	226.9	0.45	0.05	1471.
30	5.73	32.63	30	25.74	226.9	0.68	0.10	1471.
50	5.68	32.64	50	25.75	225.8	1.13	0.29	1471.
75	5.66	32.65	75	25.76	225.1	1.70	0.65	1472.
100	5.65	32.66	99	25.77	224.5	2.26	1.15	1472.
125	4.01	33.25	124	26.42	162.8	2.74	1.70	1467.
150	4.00	33.54	149	26.64	141.5	3.12	2.23	1467.
175	3.93	33.67	174	26.76	131.1	3.46	2.79	1468.
200	3.77	33.74	199	26.83	124.1	3.78	3.40	1467.
225	3.72	33.79	223	26.88	120.0	4.08	4.06	1468.
250	3.70	33.84	248	26.91	116.7	4.38	4.77	1468.
300	3.66	33.92	298	26.98	110.7	4.95	6.37	1469.
400	3.63	34.05	397	27.09	101.4	6.01	10.13	1471.
500	3.50	34.15	496	27.18	93.4	6.98	14.57	1472.
600	3.34	34.23	595	27.26	86.5	7.88	19.60	1473.
800	3.07	34.32	793	27.36	78.2	9.52	31.28	1475.
1000	2.80	34.40	990	27.44	70.6	11.01	44.90	1477.
1200	2.57	34.45	1188	27.50	65.5	12.37	60.09	1480.



PACIFIC OCEANOGRAPHIC GROUP

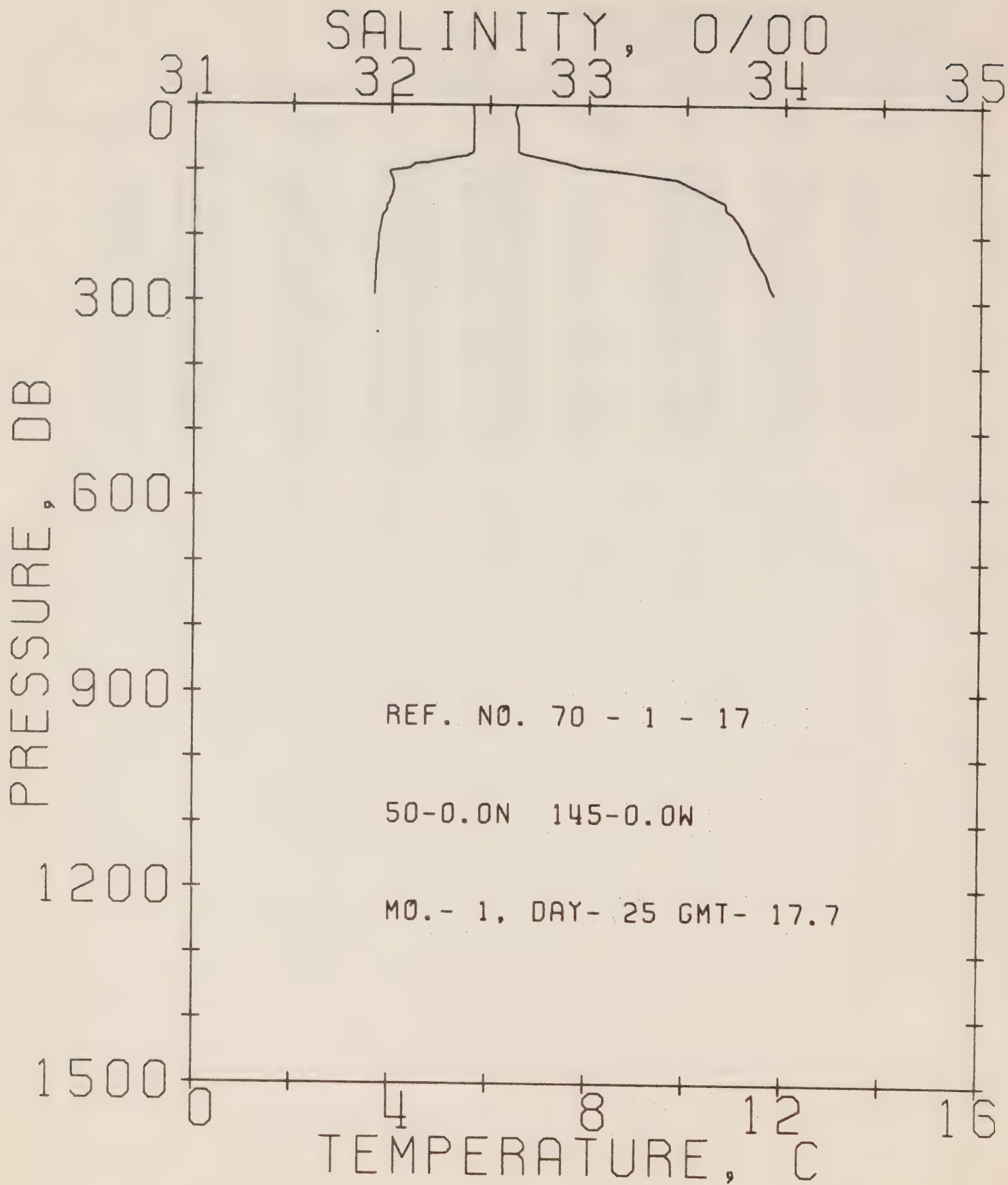
REFERENCE NO. 70- 1- 16

DATE 22/ 1/70

POSITION 50- 0.0N, 145- 0.0W GMT 17.6

RESULTS OF STP CAST 29 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.69	32.65	0	25.76	224.4	0.00	0.00	1471.
10	5.69	32.64	10	25.75	225.5	0.22	0.01	1471.
20	5.69	32.64	20	25.75	225.6	0.45	0.05	1471.
30	5.66	32.66	30	25.77	223.9	0.68	0.10	1471.
50	5.66	32.66	50	25.77	224.1	1.12	0.29	1471.
75	5.66	32.66	75	25.77	224.3	1.68	0.64	1472.
100	5.05	32.78	99	25.93	209.1	2.24	1.14	1470.
125	4.07	33.30	124	26.45	159.8	2.69	1.65	1467.
150	4.09	33.60	149	26.69	137.3	3.05	2.16	1468.
175	3.91	33.71	174	26.79	127.8	3.38	2.70	1468.
200	3.79	33.78	199	26.85	121.8	3.69	3.30	1468.
225	3.74	33.83	223	26.91	117.2	3.99	3.95	1468.
250	3.72	33.86	248	26.93	114.9	4.28	4.65	1468.



PACIFIC OCEANOGRAPHIC GROUP

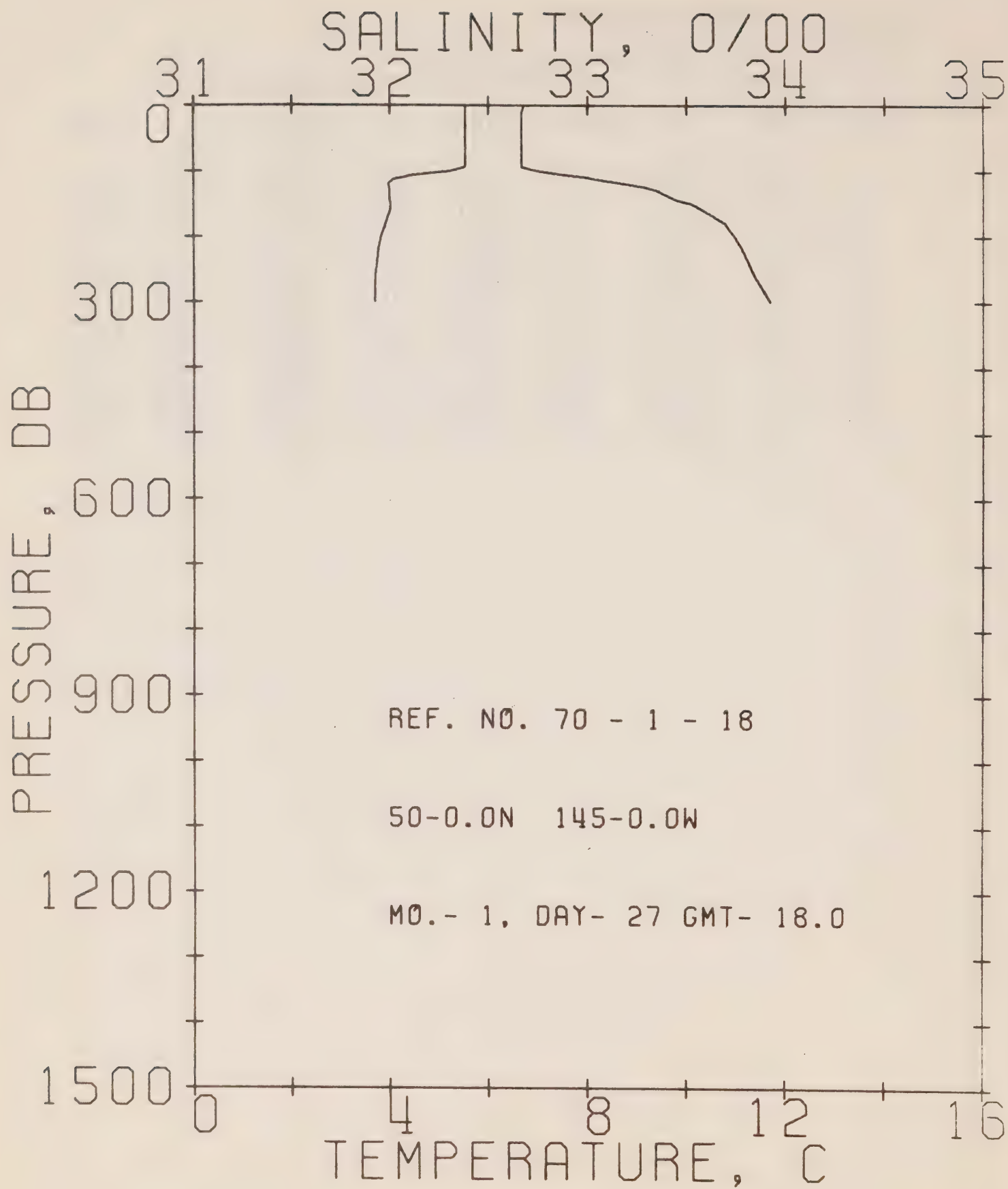
REFERENCE NO. 70- 1- 17

DATE 25/ 1/70

POSITION 50- 0.0N, 145- 0.0W GMT 17.7

RESULTS OF STP CAST 32 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.67	32.64	0	25.75	224.9	0.00	0.00	1471.
10	5.68	32.63	10	25.74	226.1	0.23	0.01	1471.
20	5.69	32.64	20	25.75	225.6	0.45	0.05	1471.
30	5.70	32.65	30	25.75	225.1	0.68	0.10	1471.
50	5.70	32.65	50	25.75	225.3	1.13	0.29	1472.
75	5.61	32.67	75	25.78	223.2	1.69	0.65	1472.
100	4.07	33.09	99	26.29	175.1	2.19	1.09	1466.
125	4.06	33.53	124	26.63	142.7	2.58	1.53	1467.
150	3.98	33.70	149	26.77	129.3	2.92	2.01	1467.
175	3.84	33.76	174	26.83	123.7	3.23	2.53	1467.
200	3.76	33.81	199	26.88	119.2	3.54	3.11	1468.
225	3.73	33.84	223	26.91	116.8	3.83	3.75	1468.
250	3.69	33.89	248	26.95	112.9	4.12	4.44	1468.



PACIFIC OCEANOGRAPHIC GROUP

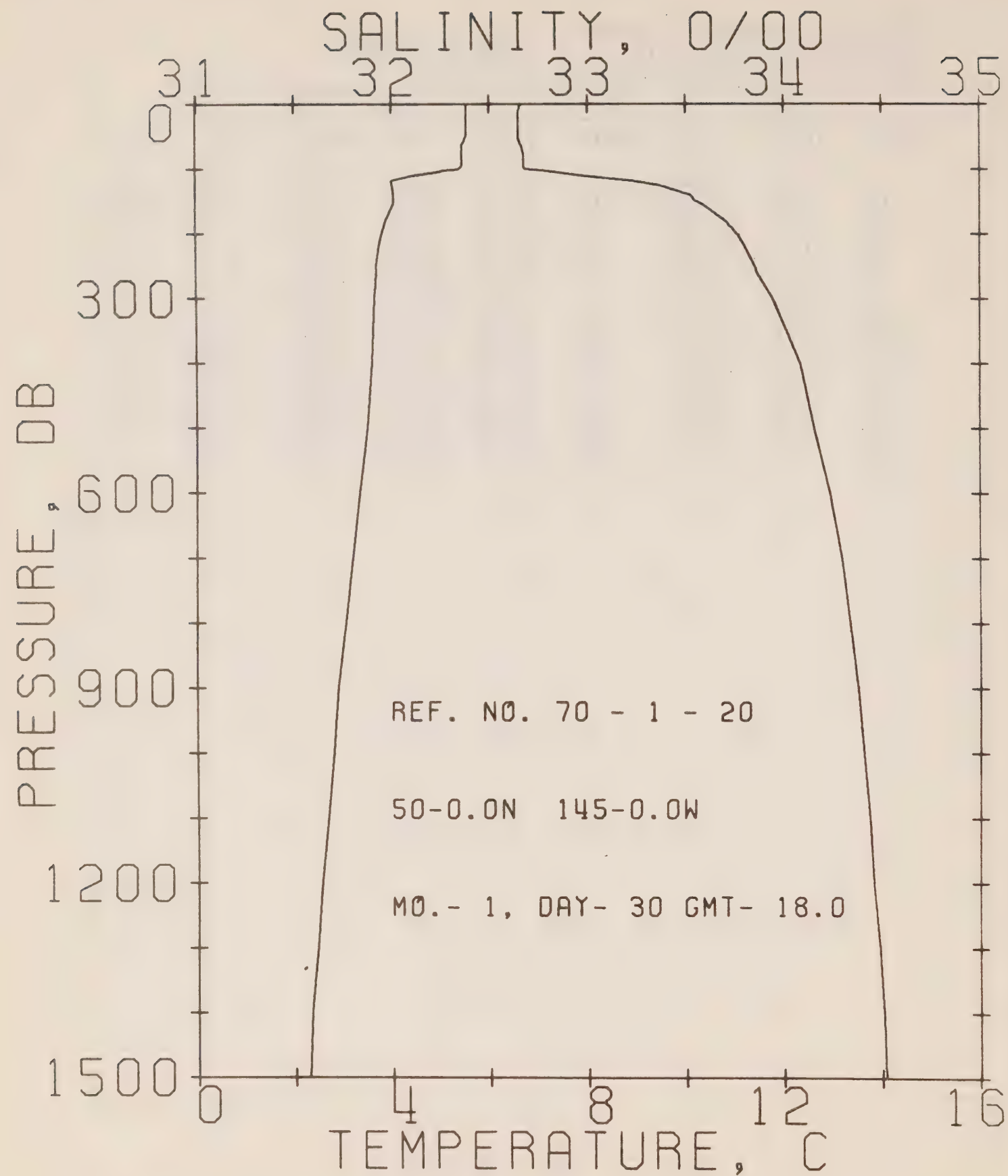
REFERENCE NO. 70- 1- 18

DATE 27/ 1/70

POSITION 50- 0.0N, 145- 0.0W GMT 18.0

RESULTS OF STP CAST 24 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.54	32.68	0	25.80	220.4	0.00	0.00	1470.
10	5.54	32.67	10	25.79	221.5	0.22	0.01	1470.
20	5.54	32.67	20	25.79	221.6	0.44	0.05	1470.
30	5.54	32.67	30	25.79	221.8	0.66	0.10	1471.
50	5.54	32.67	50	25.79	222.0	1.11	0.28	1471.
75	5.54	32.67	75	25.79	222.2	1.66	0.64	1471.
100	5.27	32.74	99	25.88	213.9	2.22	1.13	1471.
125	3.99	33.29	124	26.45	159.8	2.67	1.65	1467.
150	4.03	33.52	149	26.63	143.0	3.05	2.18	1467.
175	3.97	33.67	174	26.75	131.5	3.39	2.75	1468.
200	3.84	33.75	199	26.83	124.5	3.71	3.35	1468.
225	3.76	33.80	223	26.87	120.3	4.02	4.02	1468.
250	3.73	33.83	248	26.91	117.3	4.32	4.74	1468.
300	3.69	33.93	298	26.98	110.3	4.89	6.33	1469.



PACIFIC OCEANOGRAPHIC GROUP

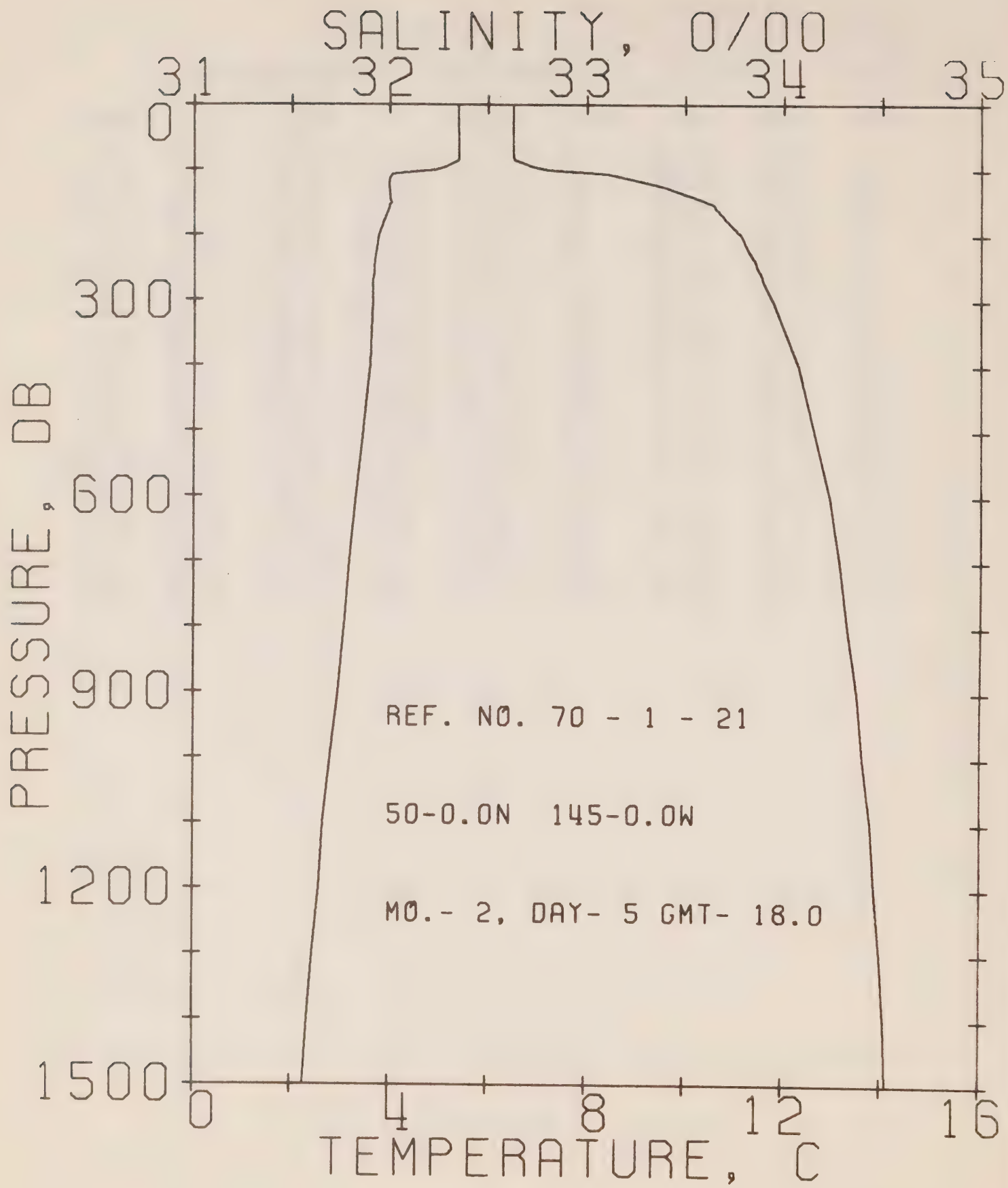
REFERENCE NO. 70- 1- 20

DATE 30/ 1/70

POSITION 50- 0.0N, 145- 0.0W GMT 18.0

RESULTS OF STP CAST 37 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.54	32.66	0	25.78	221.9	0.00	0.00	1470.
10	5.54	32.65	10	25.77	223.0	0.22	0.01	1470.
20	5.54	32.65	20	25.77	223.1	0.45	0.05	1470.
30	5.54	32.65	30	25.77	223.3	0.67	0.10	1471.
50	5.54	32.65	50	25.77	223.5	1.12	0.28	1471.
75	5.45	32.68	75	25.81	220.5	1.67	0.64	1471.
100	5.41	32.69	99	25.82	219.5	2.22	1.13	1471.
125	4.02	33.36	124	26.50	154.9	2.68	1.65	1467.
150	4.05	33.56	149	26.66	140.4	3.04	2.16	1468.
175	3.93	33.68	174	26.77	130.0	3.38	2.72	1468.
200	3.82	33.77	199	26.84	122.8	3.70	3.32	1468.
225	3.74	33.82	223	26.89	118.5	4.00	3.97	1468.
250	3.70	33.86	248	26.93	115.2	4.29	4.68	1468.
300	3.65	33.95	298	27.00	108.4	4.85	6.25	1469.
400	3.60	34.09	397	27.12	98.1	5.88	9.91	1470.
500	3.50	34.16	496	27.19	92.6	6.84	14.27	1472.
600	3.35	34.24	595	27.26	85.8	7.73	19.25	1473.
800	3.06	34.34	793	27.37	76.6	9.34	30.74	1475.
1000	2.80	34.41	990	27.45	69.9	10.80	44.08	1477.
1200	2.56	34.46	1188	27.51	64.6	12.15	59.11	1480.
1500	2.28	34.52	1483	27.58	58.6	13.98	84.26	1484.



PACIFIC OCEANOGRAPHIC GROUP

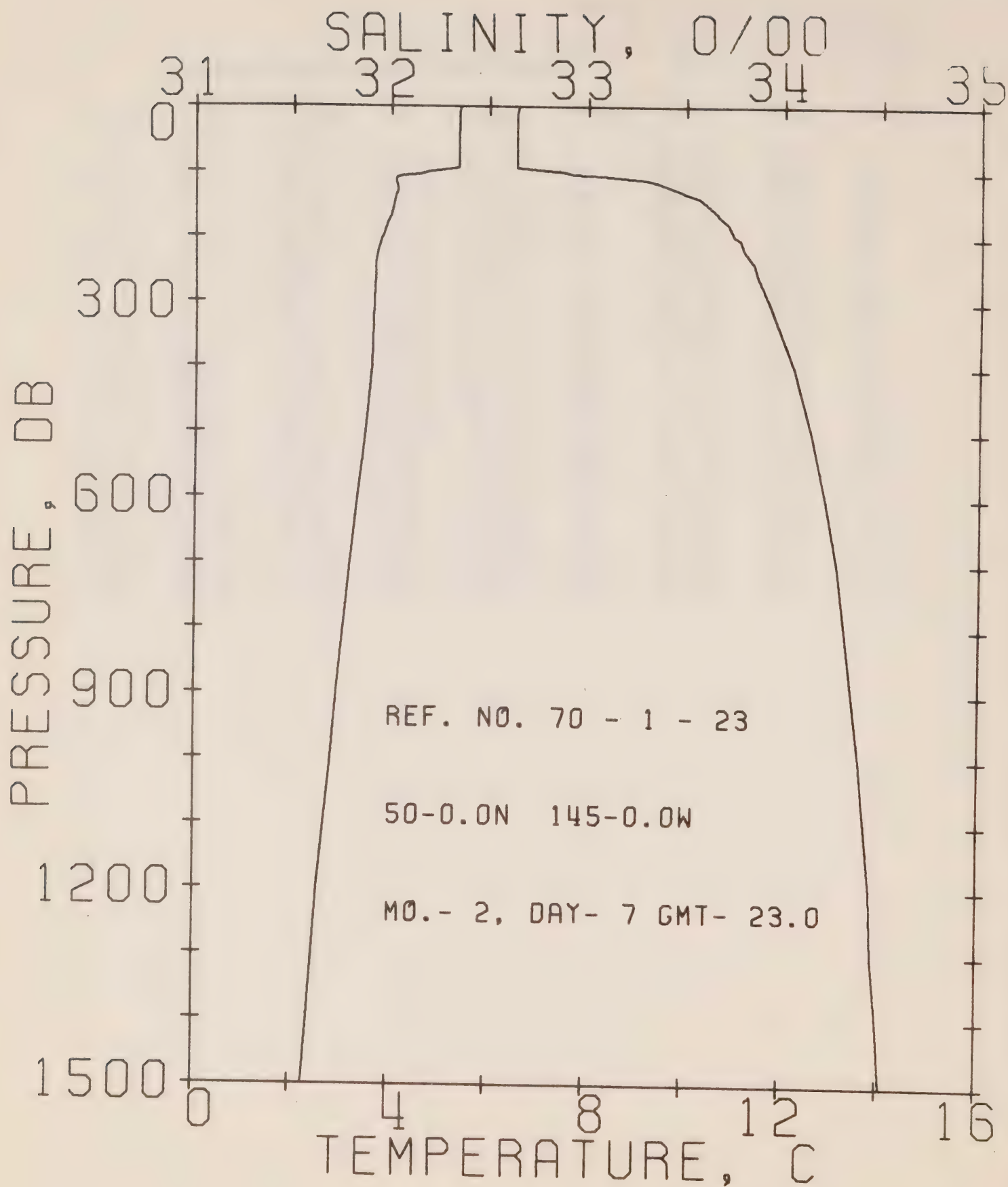
REFERENCE NO. 70- 1- 21

DATE 5/ 2/70

POSITION 50- 0.0N, 145- 0.0W GMT 18.0

RESULTS OF STP CAST 37 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.40	32.63	0	25.77	222.6	0.00	0.00	1470.
10	5.40	32.63	10	25.77	223.0	0.22	0.01	1470.
20	5.40	32.63	20	25.77	223.1	0.45	0.05	1470.
30	5.40	32.63	30	25.77	223.2	0.67	0.10	1470.
50	5.41	32.63	50	25.77	223.5	1.12	0.28	1470.
75	5.41	32.63	75	25.77	223.7	1.67	0.64	1471.
100	4.96	32.80	99	25.96	206.1	2.22	1.13	1470.
125	3.99	33.38	124	26.52	152.9	2.65	1.61	1467.
150	4.03	33.61	149	26.70	135.9	3.01	2.12	1468.
175	3.92	33.71	174	26.79	128.3	3.34	2.66	1468.
200	3.80	33.79	199	26.86	121.1	3.65	3.26	1468.
225	3.73	33.83	223	26.90	117.6	3.95	3.90	1468.
250	3.70	33.87	248	26.94	114.4	4.24	4.60	1468.
300	3.67	33.95	298	27.00	108.5	4.79	6.16	1469.
400	3.61	34.08	397	27.11	99.0	5.83	9.84	1471.
500	3.48	34.16	496	27.19	92.4	6.79	14.21	1472.
600	3.34	34.24	595	27.27	85.7	7.68	19.19	1473.
800	3.09	34.33	793	27.36	77.7	9.31	30.77	1475.
1000	2.83	34.41	990	27.45	70.2	10.78	44.25	1477.
1200	2.59	34.47	1188	27.52	64.2	12.11	59.17	1480.
1500	2.27	34.53	1483	27.59	57.7	13.92	84.03	1483.



PACIFIC OCEANOGRAPHIC GROUP

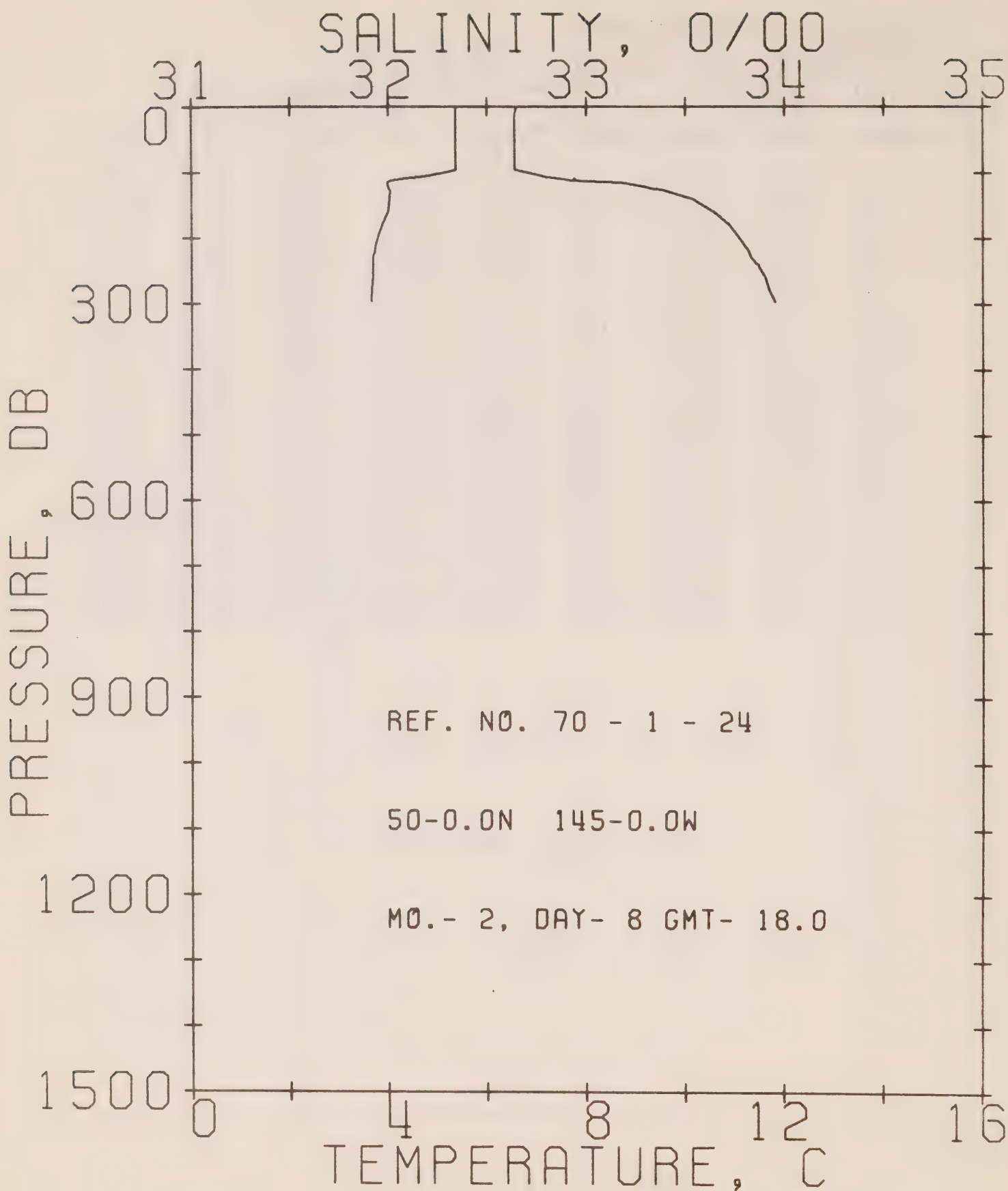
REFERENCE NO. 70- 1- 23

DATE 7/ 2/70

POSITION 50- 0.0N, 145- 0.0W GMT 23.0

RESULTS OF STP CAST 38 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.43	32.65	0	25.79	221.5	0.00	0.00	1470.
10	5.40	32.64	10	25.78	222.2	0.22	0.01	1470.
20	5.40	32.64	20	25.78	222.3	0.44	0.05	1470.
30	5.40	32.64	30	25.78	222.4	0.67	0.10	1470.
50	5.39	32.64	50	25.78	222.5	1.11	0.28	1470.
75	5.39	32.64	75	25.78	222.8	1.67	0.64	1471.
100	4.82	32.86	99	26.02	200.2	2.22	1.13	1469.
125	4.12	33.43	124	26.55	150.7	2.64	1.61	1467.
150	4.07	33.61	149	26.69	136.9	3.00	2.11	1468.
175	3.98	33.70	174	26.77	129.4	3.33	2.66	1468.
200	3.85	33.76	199	26.83	124.0	3.65	3.26	1468.
225	3.74	33.81	223	26.89	119.0	3.95	3.92	1468.
250	3.70	33.86	248	26.93	115.1	4.24	4.62	1468.
300	3.67	33.93	298	26.99	110.0	4.80	6.20	1469.
400	3.62	34.06	397	27.10	100.6	5.86	9.93	1471.
500	3.50	34.15	496	27.18	93.4	6.83	14.36	1472.
600	3.35	34.22	595	27.25	87.3	7.73	19.41	1473.
800	3.07	34.32	793	27.36	78.1	9.38	31.11	1475.
1000	2.83	34.40	990	27.44	71.0	10.87	44.75	1477.
1200	2.57	34.46	1188	27.51	64.8	12.22	59.94	1480.
1500	2.28	34.52	1483	27.58	58.6	14.08	85.47	1484.



PACIFIC OCEANOGRAPHIC GROUP

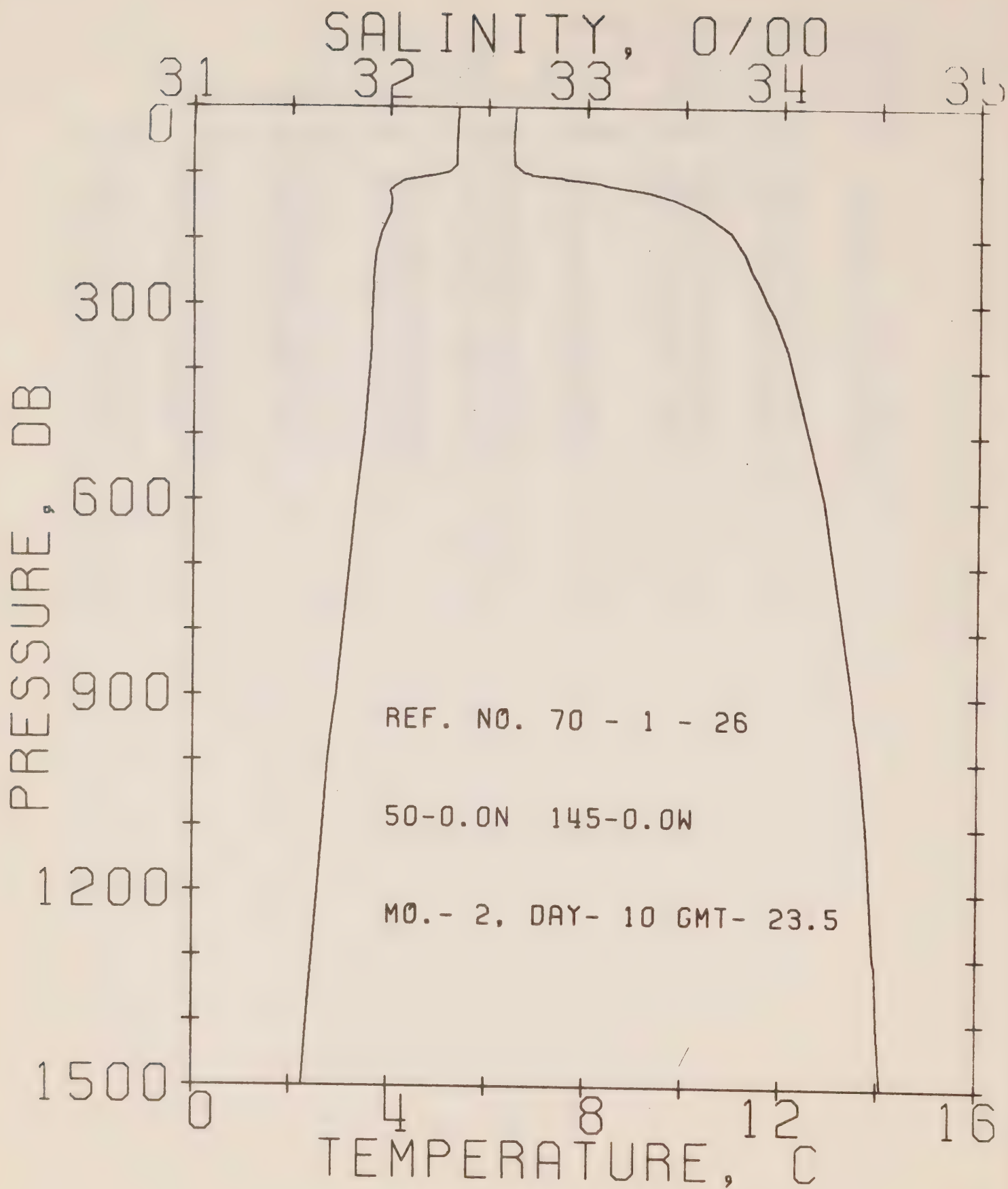
REFERENCE NO. 70- 1- 24

DATE 8/ 2/70

POSITION 50- 0.0N, 145- 0.0W GMT 18.0

RESULTS OF STP CAST 28 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.37	32.65	0	25.79	220.8	0.00	0.00	1469.
10	5.37	32.64	10	25.79	221.9	0.22	0.01	1470.
20	5.37	32.64	20	25.79	222.0	0.44	0.05	1470.
30	5.37	32.64	30	25.79	222.1	0.67	0.10	1470.
50	5.37	32.64	50	25.79	222.3	1.11	0.28	1470.
75	5.37	32.64	75	25.79	222.5	1.67	0.64	1471.
100	5.20	32.70	99	25.85	216.2	2.22	1.13	1470.
125	4.02	33.34	124	26.49	156.1	2.68	1.66	1467.
150	4.03	33.59	149	26.68	137.7	3.04	2.16	1468.
175	3.93	33.71	174	26.79	128.2	3.38	2.71	1468.
200	3.80	33.78	199	26.85	121.9	3.69	3.31	1468.
225	3.72	33.83	223	26.91	117.1	3.99	3.95	1468.
250	3.70	33.89	248	26.95	112.9	4.27	4.65	1468.



PACIFIC OCEANOGRAPHIC GROUP

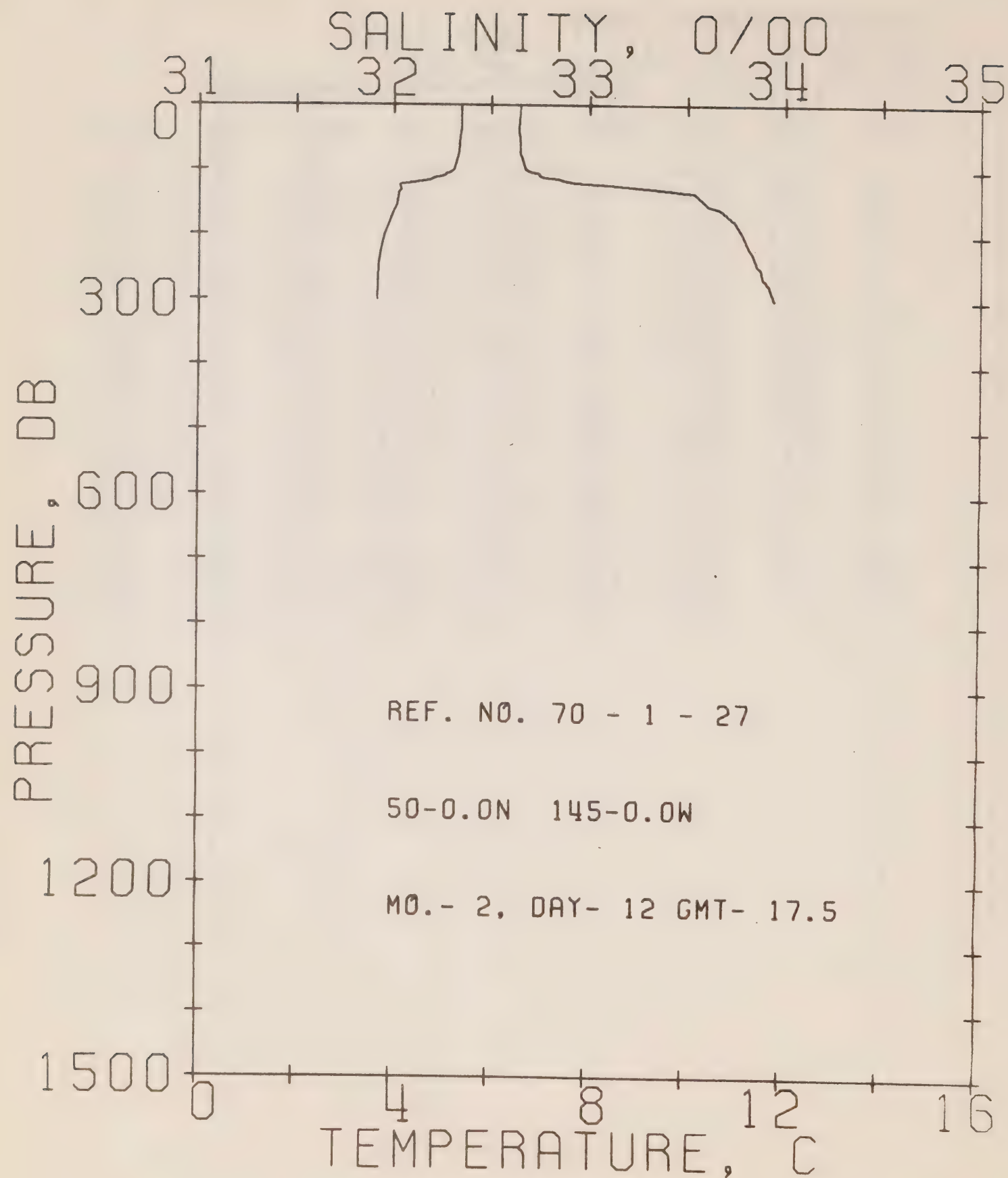
REFERENCE NO. 70- 1- 26

DATE 10/ 2/70

POSITION 50- 0.0N, 145- 0.0W GMT 23.5

RESULTS OF STP CAST 40 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.40	32.64	0	25.78	221.9	0.00	0.00	1470.
10	5.40	32.64	10	25.78	222.4	0.22	0.01	1470.
20	5.40	32.64	20	25.78	222.7	0.44	0.05	1470.
30	5.39	32.63	30	25.78	222.9	0.67	0.10	1470.
50	5.37	32.63	50	25.78	223.0	1.11	0.28	1470.
75	5.37	32.64	75	25.78	222.8	1.67	0.64	1471.
100	5.15	32.69	99	25.85	216.6	2.22	1.13	1470.
125	4.05	33.23	124	26.40	164.9	2.70	1.67	1467.
150	4.05	33.52	149	26.63	143.2	3.08	2.20	1468.
175	3.95	33.67	174	26.75	131.5	3.42	2.77	1468.
200	3.82	33.76	199	26.84	123.3	3.73	3.37	1468.
225	3.73	33.81	223	26.89	118.7	4.04	4.03	1468.
250	3.69	33.85	248	26.92	116.0	4.33	4.74	1468.
300	3.67	33.93	298	26.99	110.0	4.89	6.32	1469.
400	3.61	34.05	397	27.09	100.7	5.94	10.04	1470.
500	3.50	34.14	496	27.17	94.1	6.92	14.49	1472.
600	3.35	34.22	595	27.25	87.3	7.82	19.56	1473.
800	3.08	34.32	793	27.35	78.4	9.48	31.33	1475.
1000	2.79	34.41	990	27.45	69.8	10.96	44.88	1477.
1200	2.58	34.46	1188	27.51	64.8	12.30	59.90	1480.
1500	2.27	34.52	1483	27.58	58.5	14.15	85.28	1483.



PACIFIC OCEANOGRAPHIC GROUP

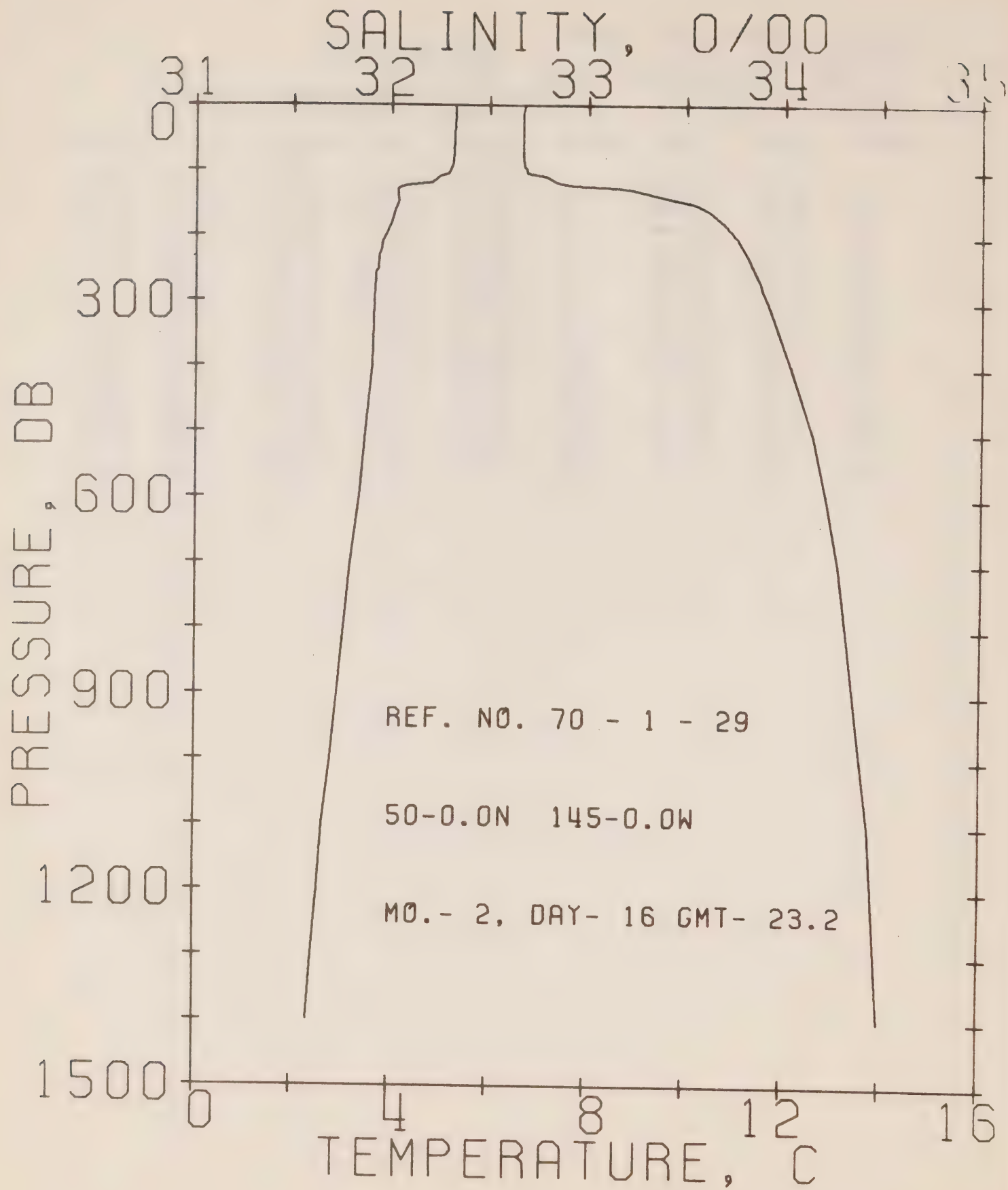
REFERENCE NO. 70- 1- 27

DATE 12/ 2/70

POSITION 50- 0.0N, 145- 0.0W GMT 17.5

RESULTS OF STP CAST 29 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.40	32.65	0	25.79	221.1	0.00	0.00	1470.
10	5.40	32.65	10	25.79	221.7	0.22	0.01	1470.
20	5.40	32.64	20	25.79	222.0	0.44	0.05	1470.
30	5.40	32.64	30	25.78	222.3	0.67	0.10	1470.
50	5.37	32.65	50	25.79	221.6	1.11	0.28	1470.
75	5.35	32.65	75	25.80	221.5	1.66	0.64	1471.
100	5.25	32.68	99	25.83	218.3	2.21	1.13	1471.
125	4.13	33.16	124	26.33	170.8	2.72	1.70	1467.
150	4.09	33.59	149	26.68	138.4	3.09	2.22	1468.
175	3.96	33.73	174	26.80	127.1	3.42	2.77	1468.
200	3.83	33.79	199	26.86	121.4	3.73	3.36	1468.
225	3.75	33.83	223	26.90	117.6	4.03	4.00	1468.
250	3.70	33.87	248	26.94	114.3	4.32	4.71	1468.
300	3.67	33.95	298	27.00	108.5	4.87	6.26	1469.



PACIFIC OCEANOGRAPHIC GROUP

REFERENCE NO. 70- 1- 29

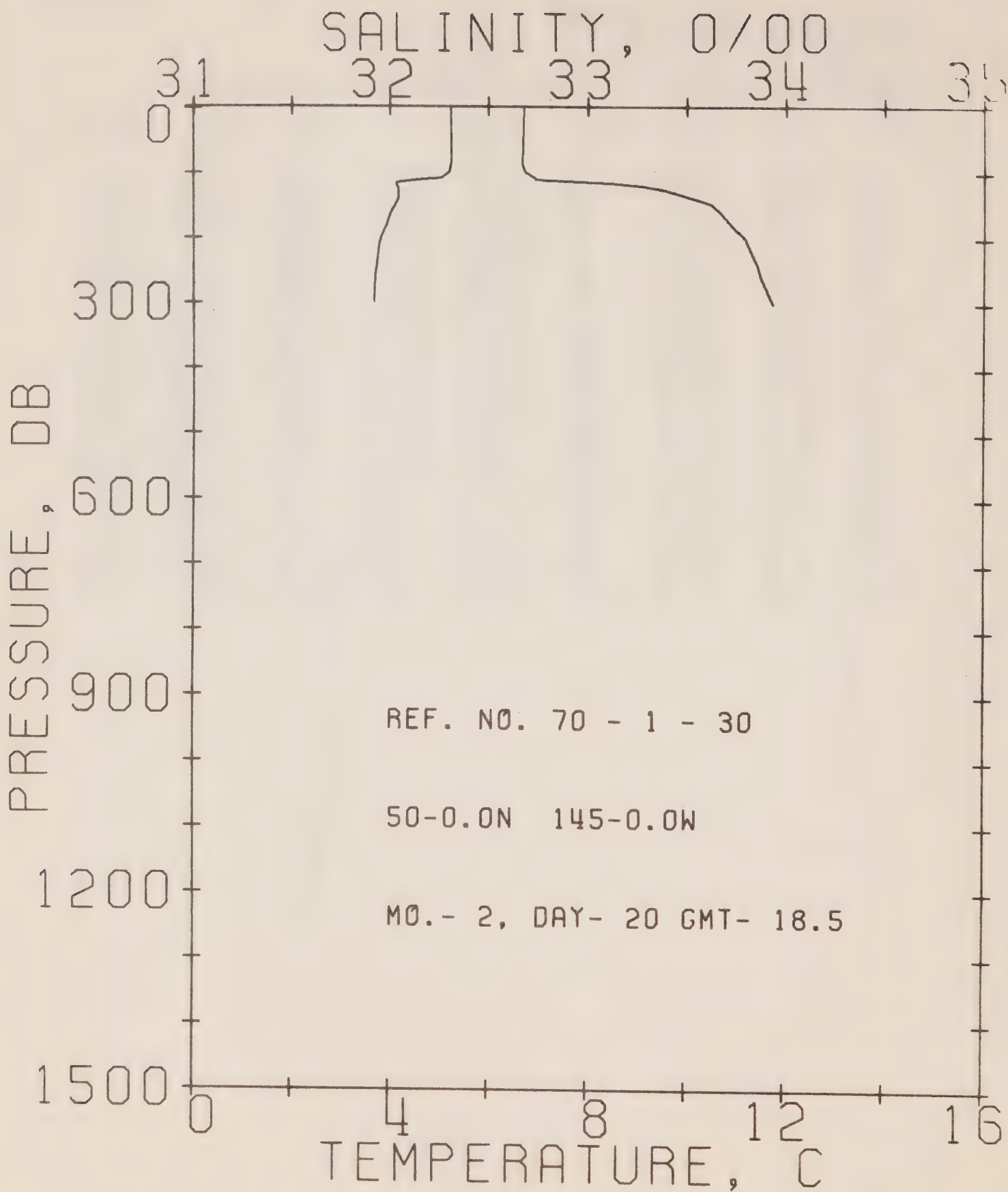
DATE 16/ 2/70

POSITION 50- 0.0N, 145- 0.0W

GMT 23.2

RESULTS OF STP CAST 40 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.32	32.68	0	25.82	218.0	0.00	0.00	1469.
10	5.32	32.67	10	25.81	219.1	0.22	0.01	1469.
20	5.32	32.67	20	25.81	219.2	0.44	0.04	1470.
30	5.31	32.67	30	25.82	219.2	0.66	0.10	1470.
50	5.30	32.67	50	25.82	219.3	1.10	0.28	1470.
75	5.28	32.67	75	25.82	219.3	1.64	0.63	1470.
100	5.21	32.69	99	25.84	217.3	2.19	1.12	1470.
125	4.23	33.11	124	26.28	175.9	2.70	1.70	1467.
150	4.15	33.54	149	26.63	142.6	3.09	2.25	1468.
175	4.04	33.68	174	26.75	131.6	3.43	2.81	1468.
200	3.90	33.76	199	26.83	124.3	3.75	3.42	1468.
225	3.79	33.81	223	26.88	119.6	4.06	4.08	1468.
250	3.74	33.85	248	26.92	116.3	4.35	4.79	1468.
300	3.67	33.92	298	26.98	110.8	4.92	6.38	1469.
400	3.62	34.04	397	27.08	102.1	5.98	10.15	1470.
500	3.49	34.15	496	27.18	93.3	6.96	14.61	1472.
600	3.37	34.22	595	27.25	87.5	7.86	19.66	1473.
800	3.07	34.32	793	27.36	78.1	9.51	31.37	1475.
1000	2.81	34.40	990	27.44	70.7	11.00	45.00	1477.
1200	2.55	34.46	1188	27.51	64.5	12.34	60.02	1480.



PACIFIC OCEANOGRAPHIC GROUP

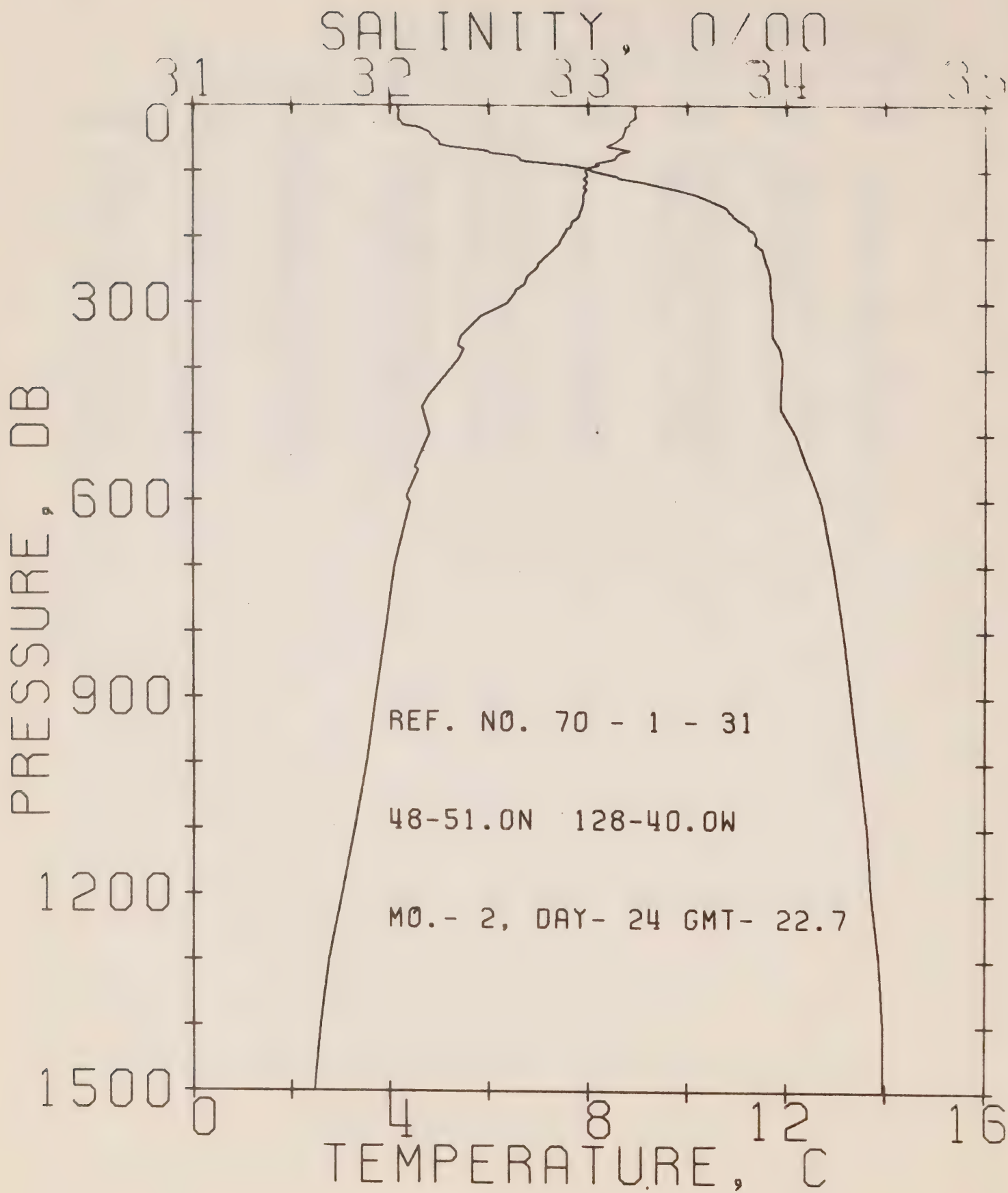
REFERENCE NO. 70- 1- 30

DATE 20/ 2/70

POSITION 50- 0.0N, 145- 0.0W GMT 18.5

RESULTS OF STP CAST 18 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.24	32.68	0	25.83	217.1	0.00	0.00	1469.
10	5.24	32.68	10	25.83	217.6	0.22	0.01	1469.
20	5.24	32.68	20	25.83	217.8	0.44	0.04	1469.
30	5.24	32.68	30	25.83	218.0	0.65	0.10	1469.
50	5.25	32.67	50	25.83	218.4	1.09	0.28	1470.
75	5.25	32.67	75	25.82	218.9	1.64	0.63	1470.
100	5.21	32.69	99	25.84	217.3	2.18	1.11	1470.
125	4.16	33.36	124	26.49	156.3	2.66	1.66	1467.
150	4.13	33.63	149	26.71	135.5	3.03	2.17	1468.
175	3.98	33.71	174	26.79	128.2	3.35	2.71	1468.
200	3.84	33.80	199	26.87	120.7	3.67	3.31	1468.
225	3.76	33.84	223	26.90	117.3	3.96	3.95	1468.
250	3.72	33.87	248	26.94	114.5	4.25	4.65	1468.
300	3.67	33.94	298	27.00	109.3	4.81	6.22	1469.



PACIFIC OCEANOGRAPHIC GROUP

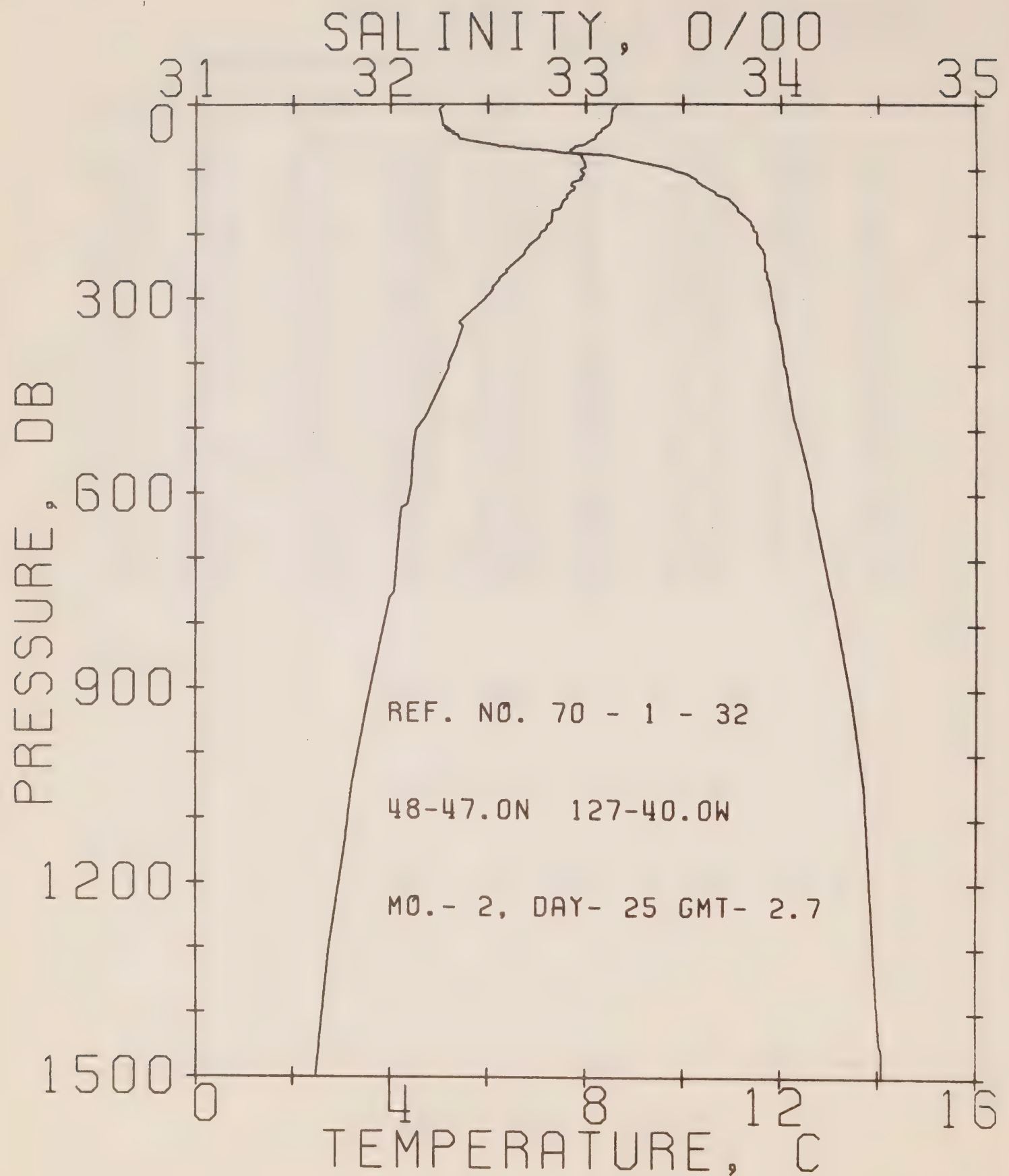
REFERENCE NO. 70- 1- 31

DATE 24/ 2/70

POSITION 48-51.0N, 128-40.0W GMT 22.7

RESULTS OF STP CAST 72 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.97	32.05	0	24.84	311.9	0.00	0.00	1483.
10	8.96	32.05	10	24.83	312.5	0.31	0.02	1483.
20	8.95	32.04	20	24.83	312.9	0.63	0.06	1483.
30	8.84	32.07	30	24.87	309.3	0.94	0.14	1483.
50	8.68	32.23	50	25.02	295.4	1.54	0.39	1483.
75	8.62	32.59	75	25.31	268.1	2.25	0.84	1483.
100	7.94	33.03	99	25.75	226.3	2.87	1.39	1482.
125	7.92	33.39	124	26.04	199.3	3.40	2.00	1483.
150	7.91	33.65	149	26.25	180.1	3.87	2.66	1483.
175	7.74	33.76	174	26.36	170.1	4.31	3.38	1483.
200	7.50	33.85	199	26.46	160.7	4.72	4.17	1483.
225	7.24	33.89	224	26.53	154.8	5.12	5.03	1482.
250	6.94	33.91	248	26.59	149.1	5.50	5.95	1481.
300	6.40	33.93	298	26.68	141.4	6.22	7.98	1480.
400	5.26	33.98	397	26.86	124.7	7.53	12.64	1477.
500	4.79	34.05	496	26.96	115.2	8.73	18.13	1477.
600	4.36	34.17	595	27.11	101.7	9.82	24.19	1477.
800	3.92	34.29	793	27.25	89.8	11.73	37.75	1479.
1000	3.53	34.37	991	27.35	81.0	13.43	53.37	1480.
1200	3.04	34.43	1188	27.45	72.3	14.96	70.45	1482.
1500	2.47	34.49	1484	27.55	62.9	16.95	97.69	1484.



PACIFIC OCEANOGRAPHIC GROUP

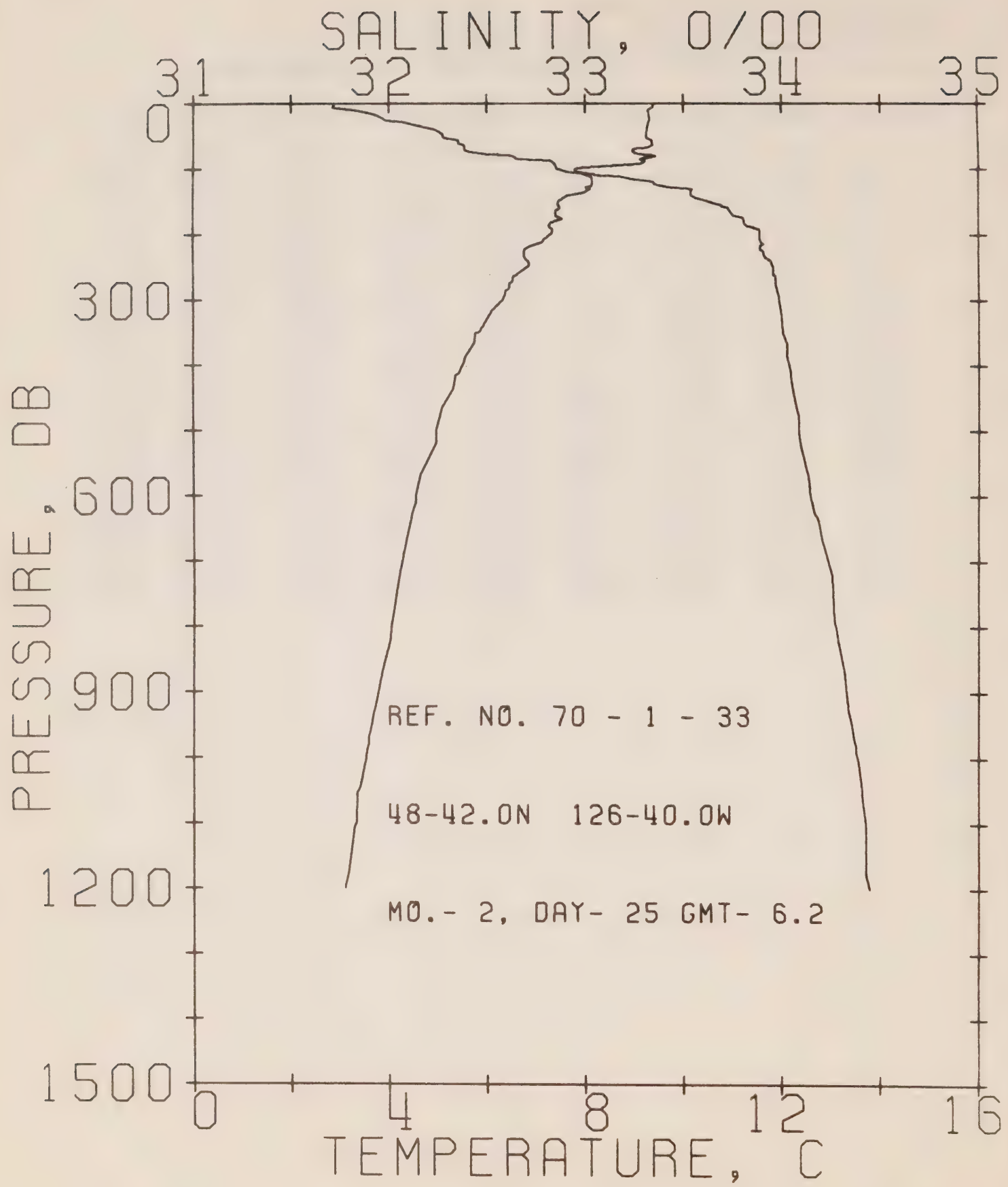
REFERENCE NO. 70- 1- 32

DATE 25/ 2/70

POSITION 48-47.0N, 127-40.0W GMT 2.7

RESULTS OF STP CAST 86 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.63	32.27	0	25.06	290.6	0.00	0.00	1482.
10	8.56	32.26	10	25.06	291.1	0.29	0.01	1482.
20	8.55	32.27	20	25.07	290.4	0.58	0.06	1482.
30	8.51	32.27	30	25.08	289.6	0.87	0.13	1482.
50	8.22	32.36	50	25.19	279.5	1.44	0.36	1481.
75	7.75	32.93	75	25.70	230.6	2.09	0.77	1480.
100	7.89	33.44	99	26.09	194.7	2.61	1.24	1482.
125	7.72	33.60	124	26.24	180.8	3.08	1.78	1482.
150	7.55	33.75	149	26.38	167.9	3.52	2.39	1482.
175	7.33	33.83	174	26.47	159.4	3.93	3.07	1482.
200	7.09	33.88	199	26.54	152.8	4.32	3.81	1481.
225	6.79	33.91	223	26.61	146.7	4.69	4.63	1480.
250	6.47	33.92	248	26.66	142.2	5.06	5.50	1480.
300	5.95	33.96	298	26.76	133.4	5.74	7.43	1478.
400	5.21	34.02	397	26.89	121.1	7.00	11.91	1477.
500	4.57	34.09	496	27.02	109.5	8.16	17.21	1476.
600	4.43	34.16	595	27.10	103.1	9.22	23.14	1477.
800	3.90	34.29	793	27.25	89.2	11.14	36.81	1479.
1000	3.36	34.40	991	27.40	76.3	12.79	51.87	1480.
1200	2.96	34.46	1188	27.48	69.2	14.24	68.04	1481.
1500	2.48	34.52	1484	27.57	60.8	16.18	94.69	1484.



PACIFIC OCEANOGRAPHIC GROUP

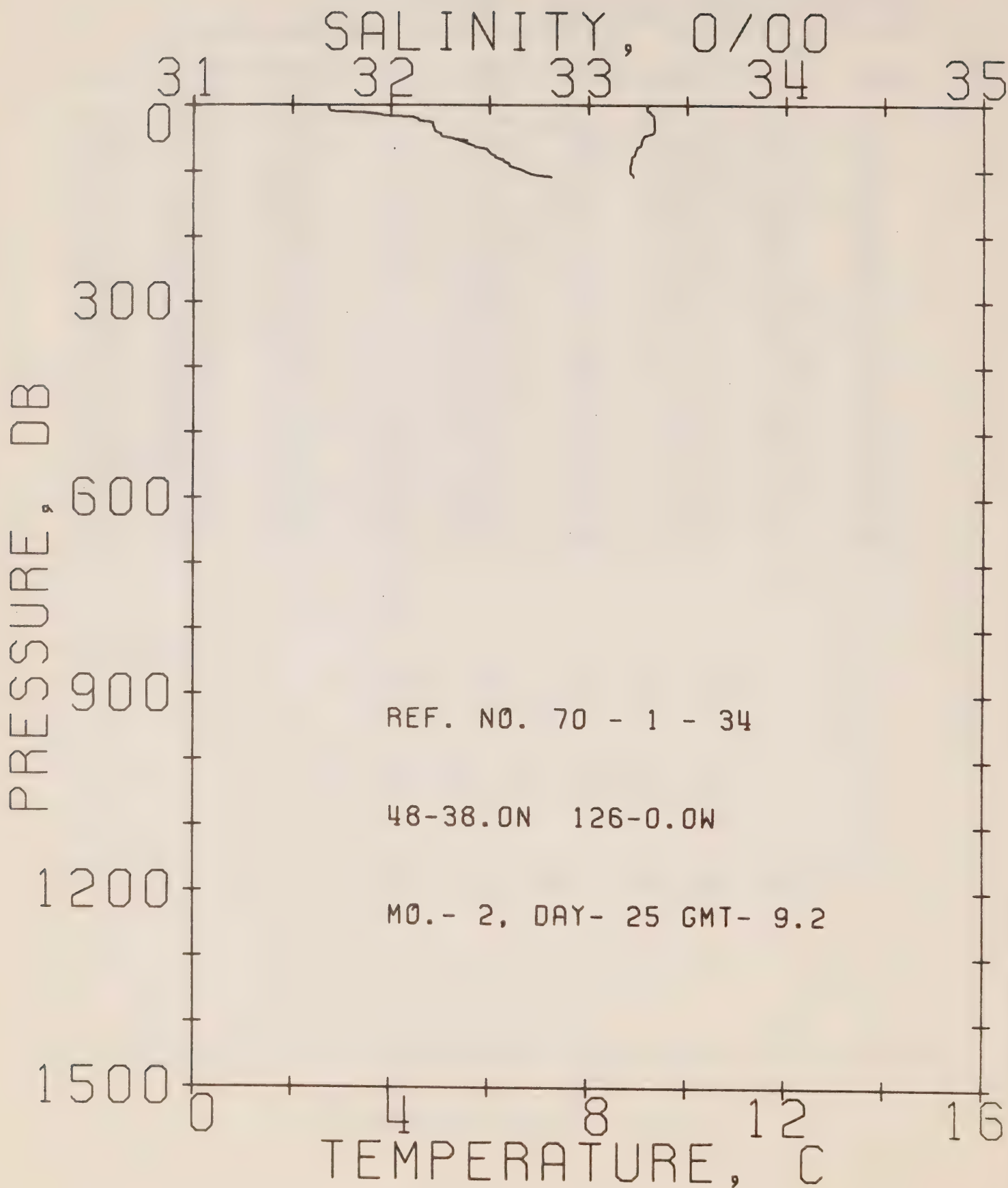
REFERENCE NO. 70- 1- 33

DATE 25/ 2/70

POSITION 48-42.0N, 126-40.0W GMT 6.2

RESULTS OF STP CAST 123 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	9.40	31.72	0	24.51	342.8	0.00	0.00	1484.
10	9.28	31.83	10	24.61	333.4	0.34	0.02	1484.
20	9.31	31.96	20	24.71	324.6	0.67	0.07	1484.
30	9.30	32.09	30	24.82	314.2	0.99	0.15	1485.
50	9.25	32.28	50	24.97	300.1	1.60	0.40	1485.
75	9.02	32.44	75	25.13	285.2	2.34	0.86	1485.
100	7.79	32.87	99	25.65	236.3	2.99	1.45	1481.
125	8.15	33.38	124	26.00	203.2	3.54	2.07	1483.
150	7.47	33.63	149	26.30	175.5	4.01	2.73	1482.
175	7.51	33.81	174	26.43	163.7	4.43	3.43	1482.
200	7.30	33.89	199	26.52	154.9	4.83	4.18	1482.
225	6.77	33.90	224	26.61	147.2	5.20	5.00	1480.
250	6.83	33.96	248	26.64	144.0	5.57	5.88	1481.
300	6.33	33.99	298	26.73	136.0	6.27	7.83	1480.
400	5.52	34.04	397	26.88	123.1	7.55	12.42	1478.
500	4.99	34.09	496	26.98	114.2	8.74	17.83	1478.
600	4.57	34.15	595	27.07	105.9	9.84	23.99	1478.
800	4.06	34.28	793	27.22	92.4	11.79	37.91	1479.
1000	3.54	34.39	991	27.36	79.9	13.52	53.67	1480.
1200	3.12	34.45	1188	27.45	71.9	15.03	70.58	1482.



PACIFIC OCEANOGRAPHIC GROUP

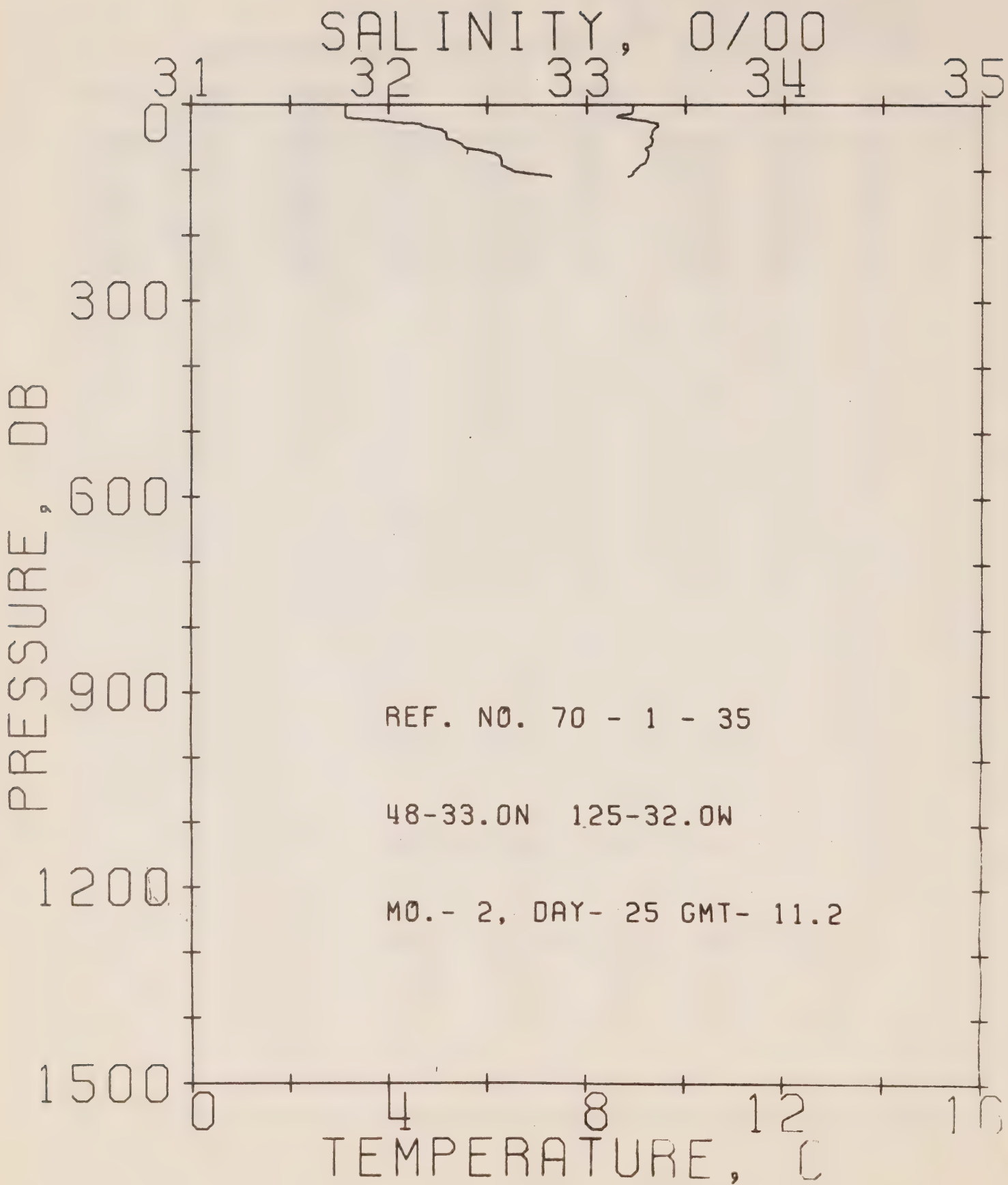
REFERENCE NO. 70- 1- 34

DATE 25/ 2/70

POSITION 48-38.0N, 126- 0.0W GMT 9.2

RESULTS OF STP CAST 37 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	9.18	31.68	0	24.51	342.5	0.00	0.00	1483.
10	9.23	31.73	10	24.54	340.0	0.34	0.02	1484.
20	9.32	32.13	20	24.84	311.8	0.67	0.07	1485.
30	9.33	32.21	30	24.90	306.1	0.97	0.15	1485.
50	9.12	32.31	50	25.01	296.2	1.58	0.39	1484.
75	8.94	32.51	75	25.20	278.7	2.30	0.85	1484.
100	8.83	32.67	99	25.34	265.7	2.98	1.46	1485.



PACIFIC OCEANOGRAPHIC GROUP

REFERENCE NO. 70- 1- 35

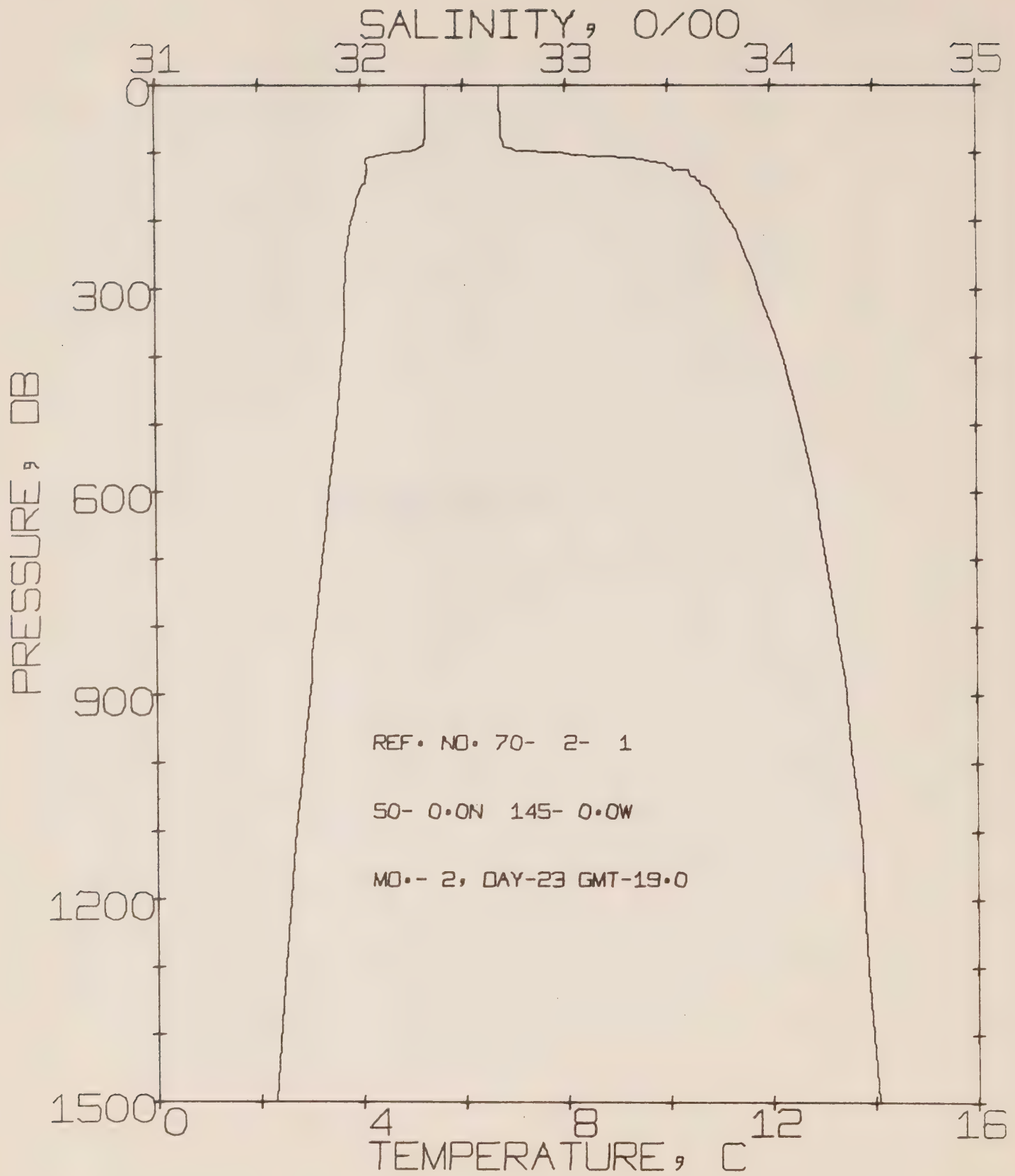
DATE 25/ 2/70

POSITION 48-33.ON, 125-32.OW GMT 11.2

RESULTS OF STP CAST 49 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.96	31.79	0	24.63	331.0	0.00	0.00	1482.
10	8.95	31.78	10	24.63	332.1	0.33	0.02	1483.
20	8.76	31.79	20	24.66	328.8	0.66	0.07	1482.
30	9.43	32.16	30	24.85	311.3	0.98	0.15	1485.
50	9.29	32.29	50	24.97	300.0	1.59	0.40	1485.
75	9.25	32.54	75	25.17	281.3	2.32	0.86	1486.
100	9.00	32.62	99	25.28	271.9	3.01	1.48	1485.

RESULTS OF STD CASTS
(P-70-2)



PACIFIC OCEANOGRAPHIC GROUP

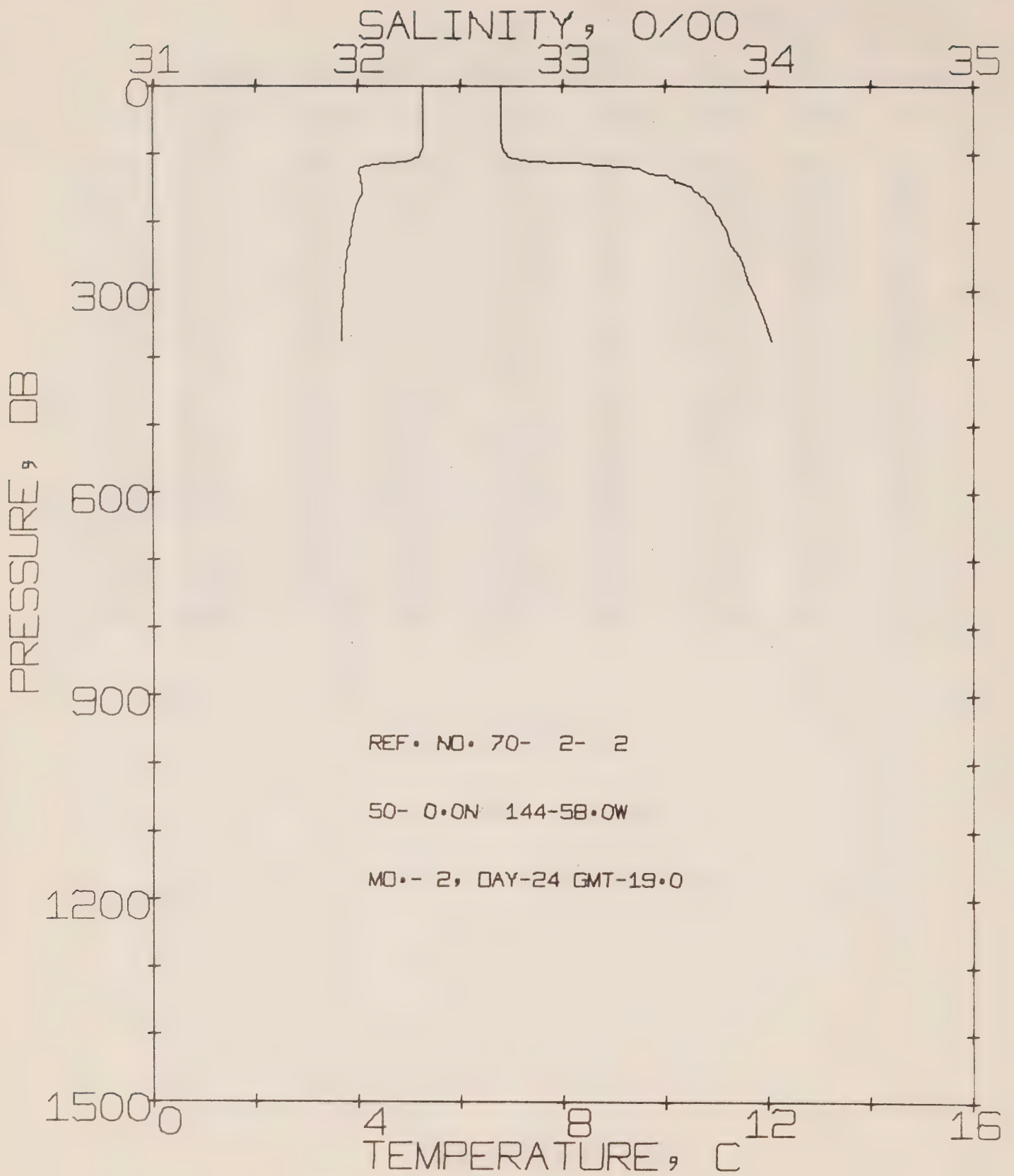
REFERENCE NO. 70- 2- 1

DATE 23/ 2/70

POSITION 50- 0.0N, 145- 0.0W GMT 19.0

RESULTS OF STP CAST 67 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.30	32.69	0	25.83	217.0	0.00	0.00	1469.
10	5.28	32.68	10	25.83	217.9	0.22	0.01	1469.
20	5.28	32.68	20	25.83	218.0	0.44	0.04	1469.
30	5.28	32.68	30	25.83	218.1	0.65	0.10	1470.
50	5.28	32.69	50	25.84	217.6	1.09	0.28	1470.
75	5.27	32.69	75	25.84	217.7	1.63	0.62	1470.
100	4.72	32.92	99	26.08	194.6	2.17	1.10	1469.
125	4.13	33.53	124	26.62	143.2	2.57	1.56	1467.
150	4.05	33.68	149	26.75	131.0	2.91	2.03	1468.
175	3.92	33.75	174	26.82	124.9	3.23	2.56	1468.
200	3.83	33.80	199	26.87	120.2	3.54	3.15	1468.
225	3.76	33.85	223	26.92	116.3	3.83	3.78	1468.
250	3.72	33.88	248	26.94	113.9	4.12	4.48	1468.
300	3.68	33.94	298	27.00	109.3	4.67	6.04	1469.
400	3.63	34.06	397	27.09	100.6	5.72	9.77	1471.
500	3.51	34.15	496	27.18	93.5	6.69	14.20	1472.
600	3.37	34.22	595	27.25	87.5	7.60	19.26	1473.
800	3.10	34.32	793	27.35	78.5	9.26	31.08	1475.
1000	2.83	34.40	990	27.44	71.1	10.75	44.72	1477.
1200	2.61	34.45	1188	27.50	65.9	12.11	59.96	1480.
1500	2.30	34.52	1483	27.58	58.9	13.98	85.65	1484.



PACIFIC OCEANOGRAPHIC GROUP

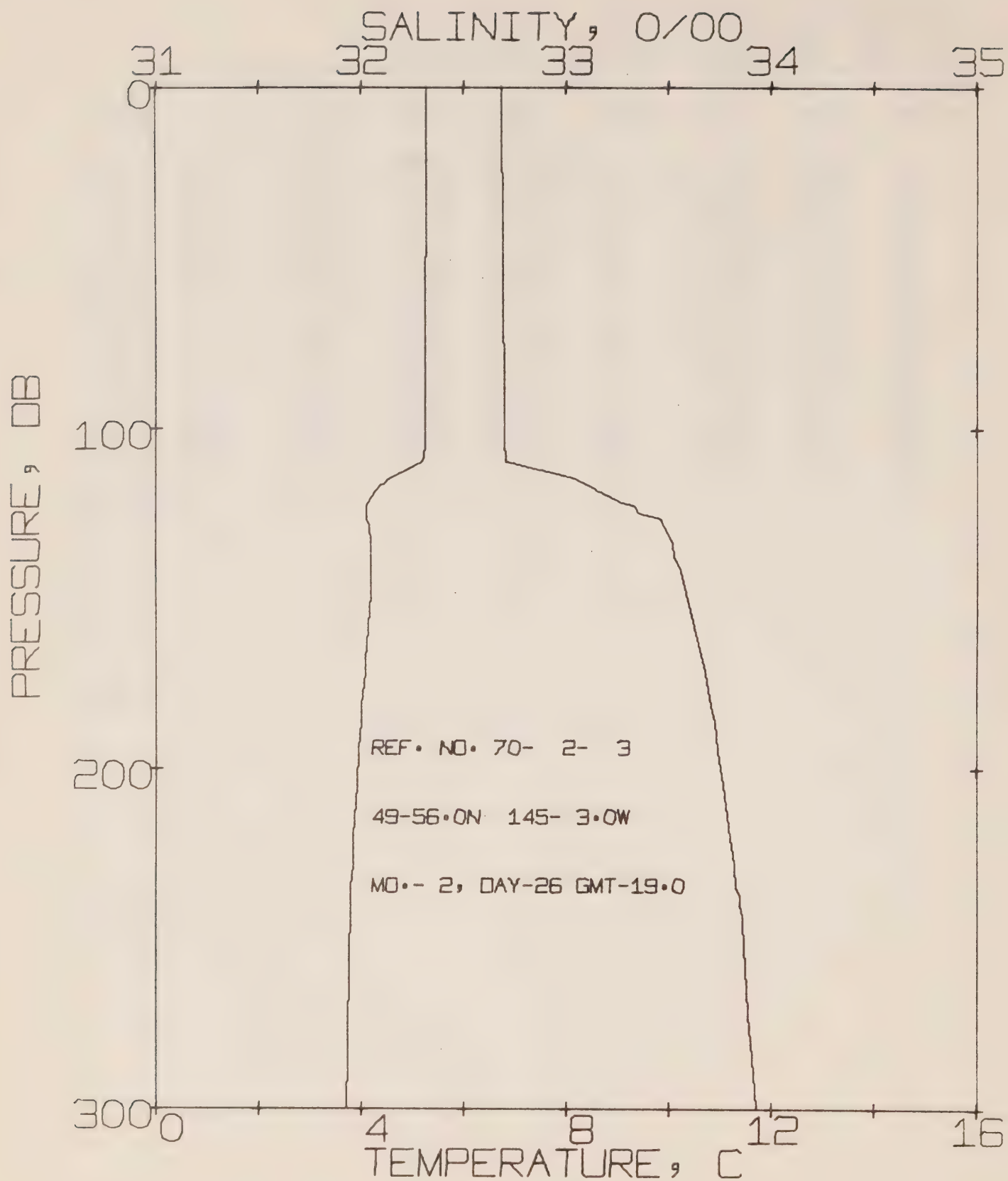
REFERENCE NO. 70- 2- 2

DATE 24/ 2/70

POSITION 50- 0.0N, 144-58.0W GMT 19.0

RESULTS OF STP CAST 46 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.28	32.70	0	25.84	216.1	0.00	0.00	1469.
10	5.27	32.70	10	25.84	216.3	0.22	0.01	1469.
20	5.27	32.70	20	25.84	216.4	0.43	0.04	1469.
30	5.27	32.70	30	25.84	216.5	0.65	0.10	1470.
50	5.27	32.70	50	25.84	216.7	1.08	0.28	1470.
75	5.27	32.70	75	25.84	216.9	1.62	0.62	1470.
100	5.23	32.72	99	25.87	214.9	2.17	1.10	1471.
125	4.02	33.39	124	26.53	152.4	2.64	1.65	1467.
150	4.07	33.63	149	26.71	135.5	3.00	2.15	1468.
175	3.99	33.72	174	26.79	127.7	3.33	2.70	1468.
200	3.90	33.77	199	26.84	123.3	3.65	3.29	1468.
225	3.84	33.81	223	26.88	120.0	3.95	3.95	1468.
250	3.80	33.86	248	26.92	116.3	4.25	4.67	1469.
300	3.72	33.92	298	26.98	110.9	4.81	6.26	1469.



PACIFIC OCEANOGRAPHIC GROUP

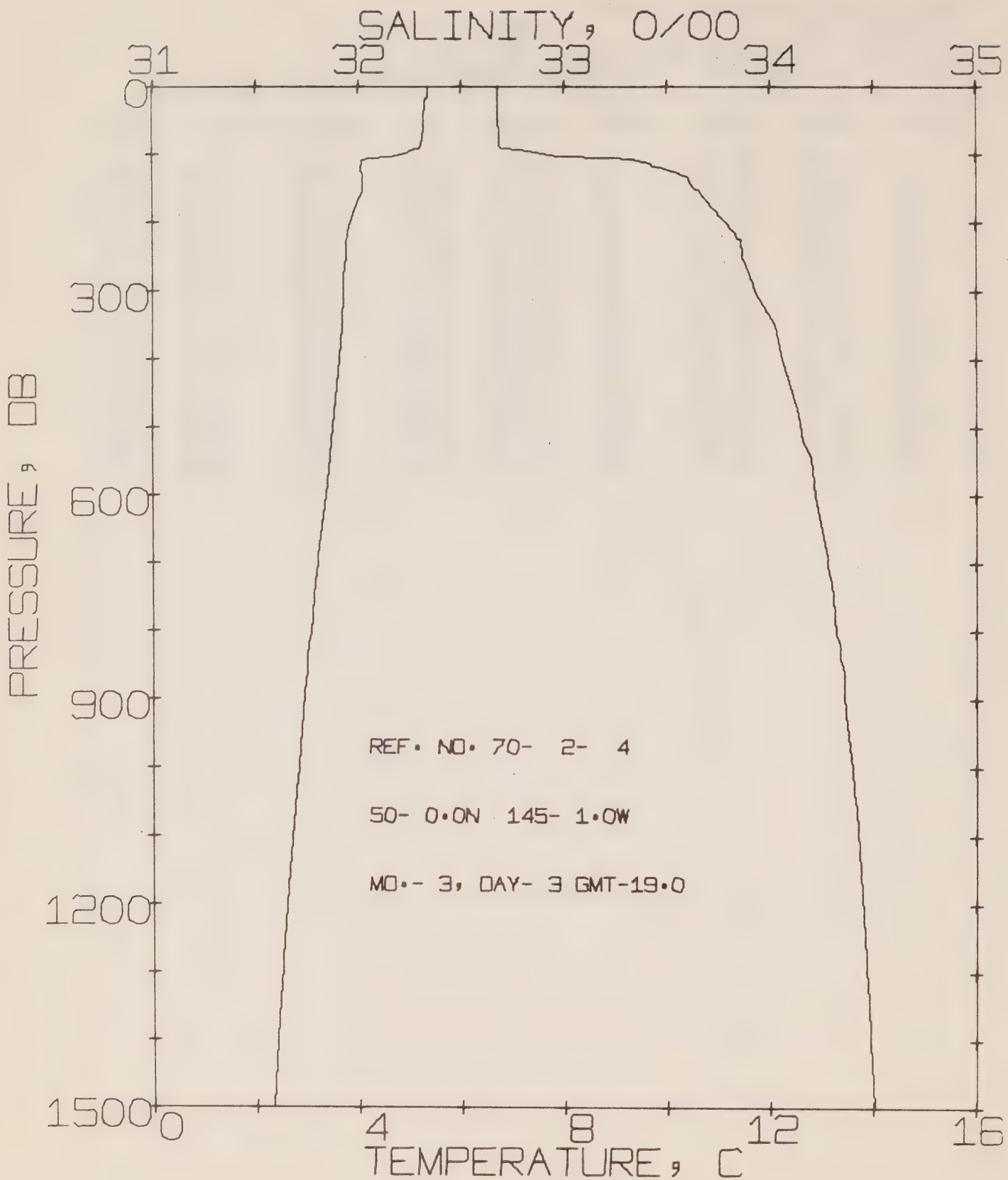
REFERENCE NO. 70- 2- 3

DATE 26/ 2/70

POSITION 49-56.0N, 145- 3.0W GMT 19.0

RESULTS OF STP CAST 35 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.28	32.69	0	25.84	216.8	0.00	0.00	1469.
10	5.28	32.69	10	25.84	217.1	0.22	0.01	1469.
20	5.28	32.69	20	25.84	217.1	0.43	0.04	1469.
30	5.27	32.69	30	25.84	217.1	0.65	0.10	1470.
50	5.27	32.69	50	25.84	217.1	1.09	0.28	1470.
75	5.27	32.70	75	25.84	217.1	1.63	0.62	1470.
100	5.26	32.70	99	25.85	217.1	2.17	1.11	1471.
125	4.12	33.35	124	26.48	156.4	2.66	1.66	1467.
150	4.18	33.59	149	26.67	139.2	3.02	2.17	1468.
175	4.05	33.69	174	26.76	131.0	3.36	2.73	1468.
200	3.93	33.75	199	26.82	125.1	3.68	3.34	1468.
225	3.84	33.81	223	26.88	120.0	3.98	4.00	1468.
250	3.77	33.87	248	26.93	115.1	4.28	4.71	1468.
300	3.70	33.93	298	26.98	110.3	4.84	6.29	1469.



PACIFIC OCEANOGRAPHIC GROUP

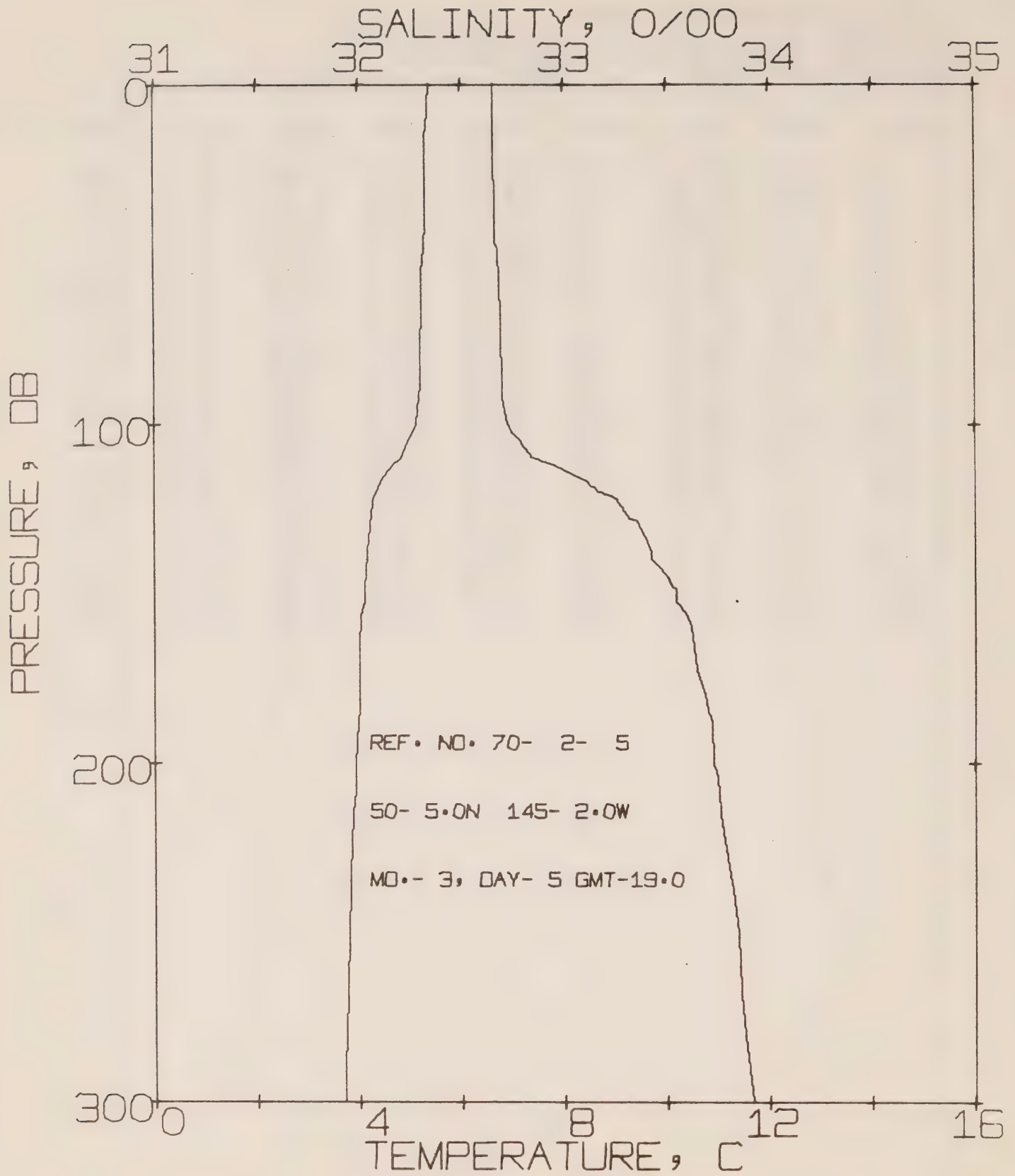
REFERENCE NO. 70- 2- 4

DATE 3/ 3/70

POSITION 50- 0.0N, 145- 1.0W GMT 19.0

RESULTS OF STP CAST 68 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.37	32.68	0	25.82	218.5	0.00	0.00	1469.
10	5.35	32.68	10	25.82	218.7	0.22	0.01	1470.
20	5.30	32.68	20	25.83	218.2	0.44	0.04	1469.
30	5.30	32.68	30	25.83	218.3	0.66	0.10	1470.
50	5.29	32.68	50	25.83	218.4	1.09	0.28	1470.
75	5.25	32.69	75	25.84	217.5	1.64	0.63	1470.
100	4.88	32.88	99	26.03	199.1	2.17	1.10	1469.
125	4.07	33.52	124	26.63	143.0	2.58	1.57	1467.
150	4.07	33.63	149	26.71	134.9	2.92	2.05	1468.
175	3.97	33.71	174	26.79	128.3	3.25	2.59	1468.
200	3.85	33.78	199	26.85	122.0	3.57	3.19	1468.
225	3.78	33.84	223	26.91	116.8	3.86	3.84	1468.
250	3.75	33.87	248	26.93	114.8	4.15	4.53	1468.
300	3.70	33.93	298	26.98	110.3	4.72	6.11	1469.
400	3.63	34.06	397	27.10	100.6	5.76	9.82	1471.
500	3.50	34.15	496	27.18	93.3	6.72	14.24	1472.
600	3.36	34.22	595	27.25	87.3	7.62	19.27	1473.
800	3.08	34.32	793	27.35	78.3	9.26	30.93	1475.
1000	2.82	34.40	990	27.44	70.9	10.75	44.50	1477.
1200	2.60	34.45	1188	27.50	65.8	12.11	59.77	1480.
1500	2.33	34.51	1483	27.57	59.9	13.99	85.62	1484.



PACIFIC OCEANOGRAPHIC GROUP

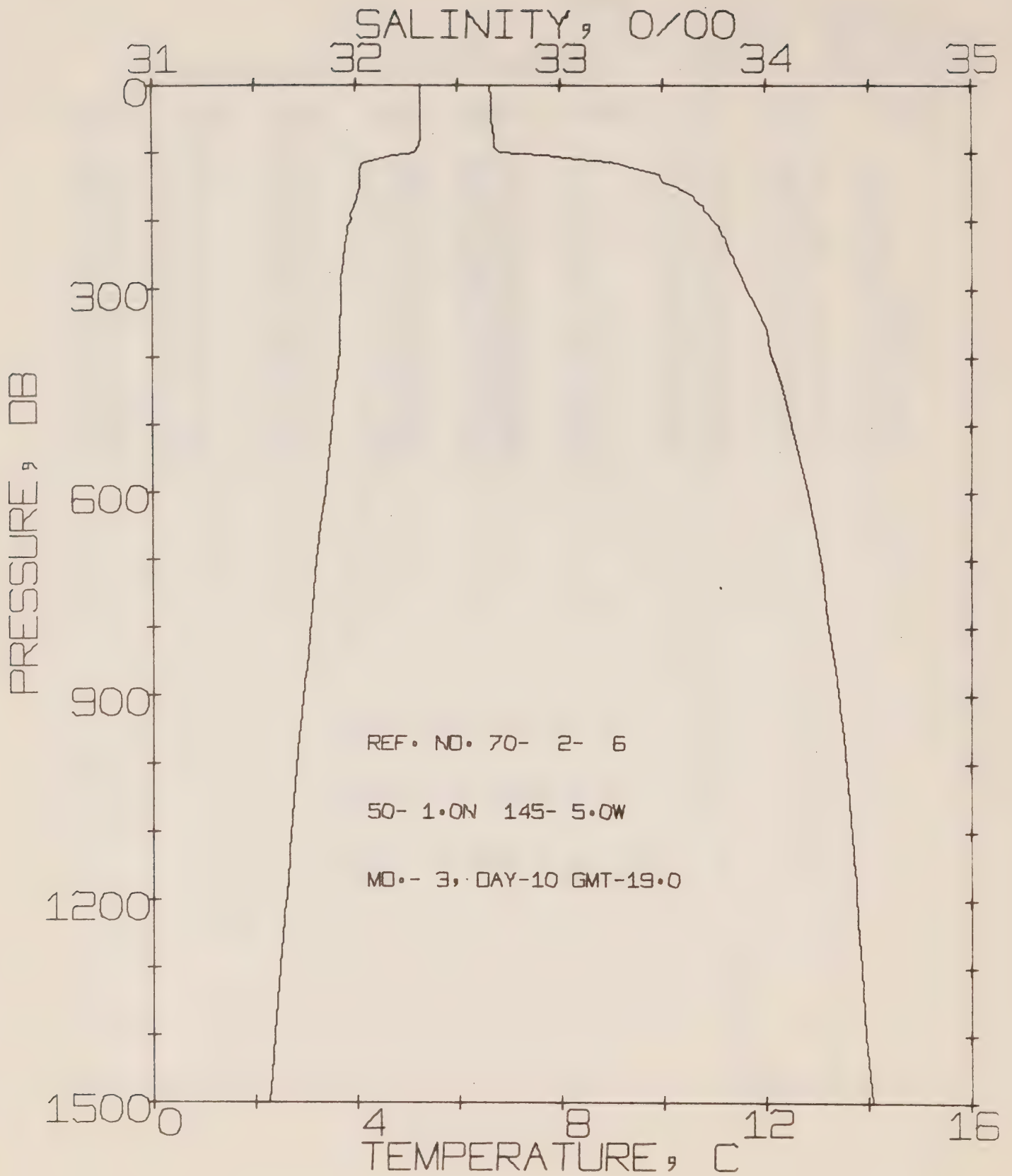
REFERENCE NO. 70- 2- 5

DATE 5/ 3/70

POSITION 50- 5.0N, 145- 2.0W GMT 19.0

RESULTS OF STP CAST 55 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.38	32.66	0	25.80	220.2	0.00	0.00	1469.
10	5.35	32.66	10	25.80	220.2	0.22	0.01	1469.
20	5.32	32.66	20	25.81	219.8	0.44	0.04	1470.
30	5.32	32.67	30	25.81	219.6	0.66	0.10	1470.
50	5.27	32.68	50	25.83	218.2	1.10	0.28	1470.
75	5.20	32.70	75	25.85	216.5	1.64	0.63	1470.
100	5.11	32.73	99	25.88	213.4	2.18	1.11	1470.
125	4.27	33.28	124	26.41	163.4	2.66	1.65	1468.
150	4.12	33.55	149	26.64	141.7	3.04	2.18	1468.
175	4.00	33.66	174	26.74	132.7	3.38	2.75	1468.
200	3.94	33.73	199	26.80	126.9	3.70	3.36	1468.
225	3.85	33.78	223	26.86	122.0	4.01	4.04	1468.
250	3.78	33.85	248	26.91	116.8	4.31	4.76	1468.
300	3.70	33.92	298	26.98	111.1	4.88	6.36	1469.



PACIFIC OCEANOGRAPHIC GROUP

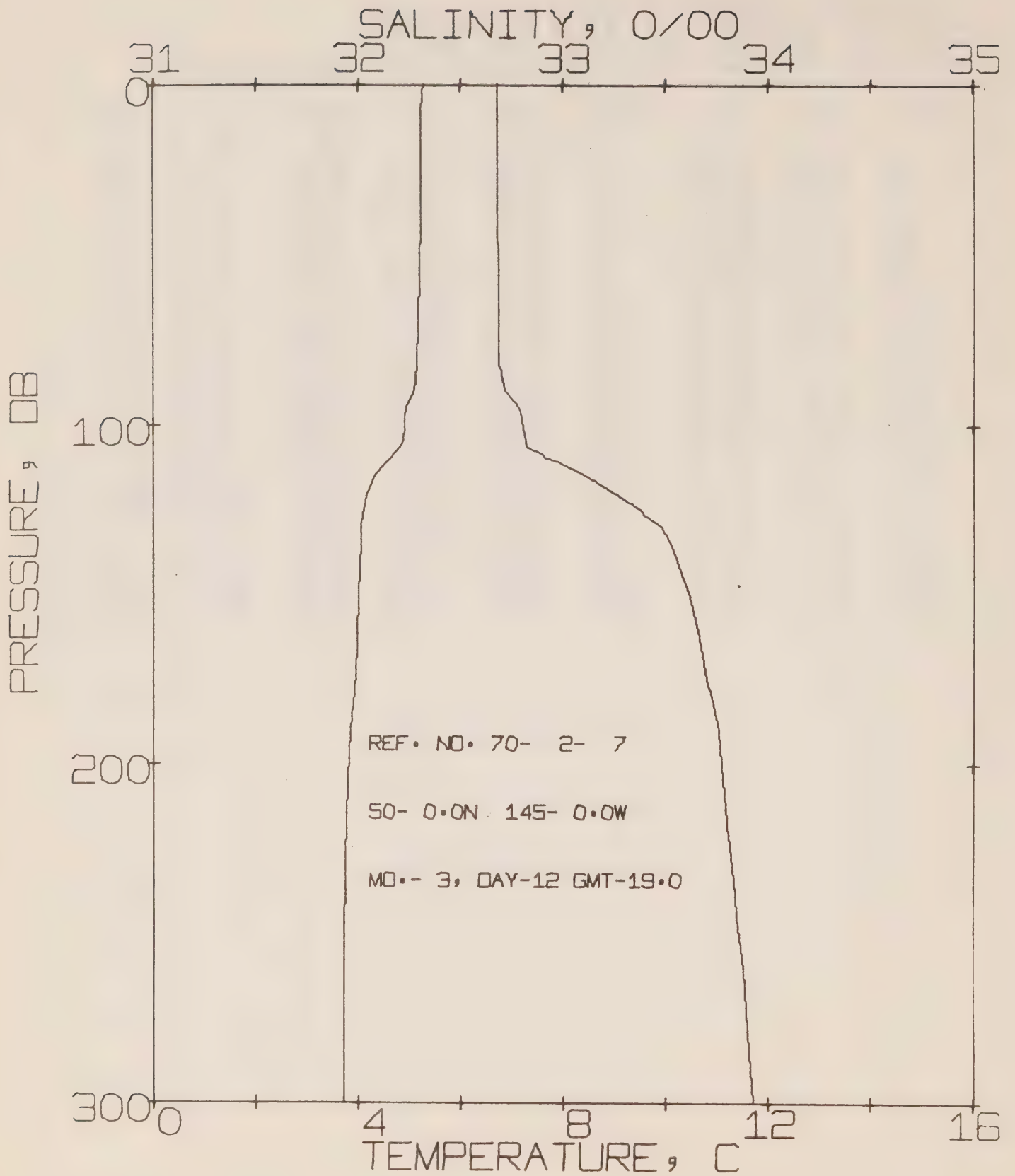
REFERENCE NO. 70- 2- 6

DATE 10/ 3/70

POSITION 50- 1.0N, 145- 5.0W GMT 19.0

RESULTS OF STP CAST 69 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.29	32.67	0	25.82	218.4	0.00	0.00	1469.
10	5.28	32.66	10	25.81	219.4	0.22	0.01	1469.
20	5.27	32.67	20	25.82	218.7	0.44	0.04	1469.
30	5.27	32.67	30	25.82	218.8	0.66	0.10	1470.
50	5.27	32.67	50	25.82	219.0	1.09	0.28	1470.
75	5.27	32.68	75	25.83	218.5	1.64	0.63	1470.
100	5.17	32.71	99	25.86	215.5	2.19	1.11	1470.
125	4.09	33.39	124	26.52	153.3	2.63	1.62	1467.
150	4.07	33.55	149	26.65	141.3	3.00	2.13	1468.
175	3.99	33.68	174	26.76	131.1	3.34	2.69	1468.
200	3.91	33.74	199	26.82	125.5	3.66	3.30	1468.
225	3.82	33.80	223	26.87	120.4	3.96	3.97	1468.
250	3.77	33.83	248	26.90	117.6	4.26	4.69	1468.
300	3.72	33.91	298	26.97	112.0	4.83	6.30	1469.
400	3.66	34.03	397	27.07	103.0	5.90	10.08	1471.
500	3.52	34.13	496	27.16	95.0	6.88	14.60	1472.
600	3.38	34.21	595	27.24	88.4	7.80	19.72	1473.
800	3.08	34.30	793	27.34	79.4	9.47	31.58	1475.
1000	2.81	34.39	990	27.44	71.4	10.97	45.31	1477.
1200	2.61	34.44	1188	27.49	66.6	12.34	60.71	1480.
1500	2.29	34.52	1483	27.58	58.8	14.22	86.48	1484.



PACIFIC OCEANOGRAPHIC GROUP

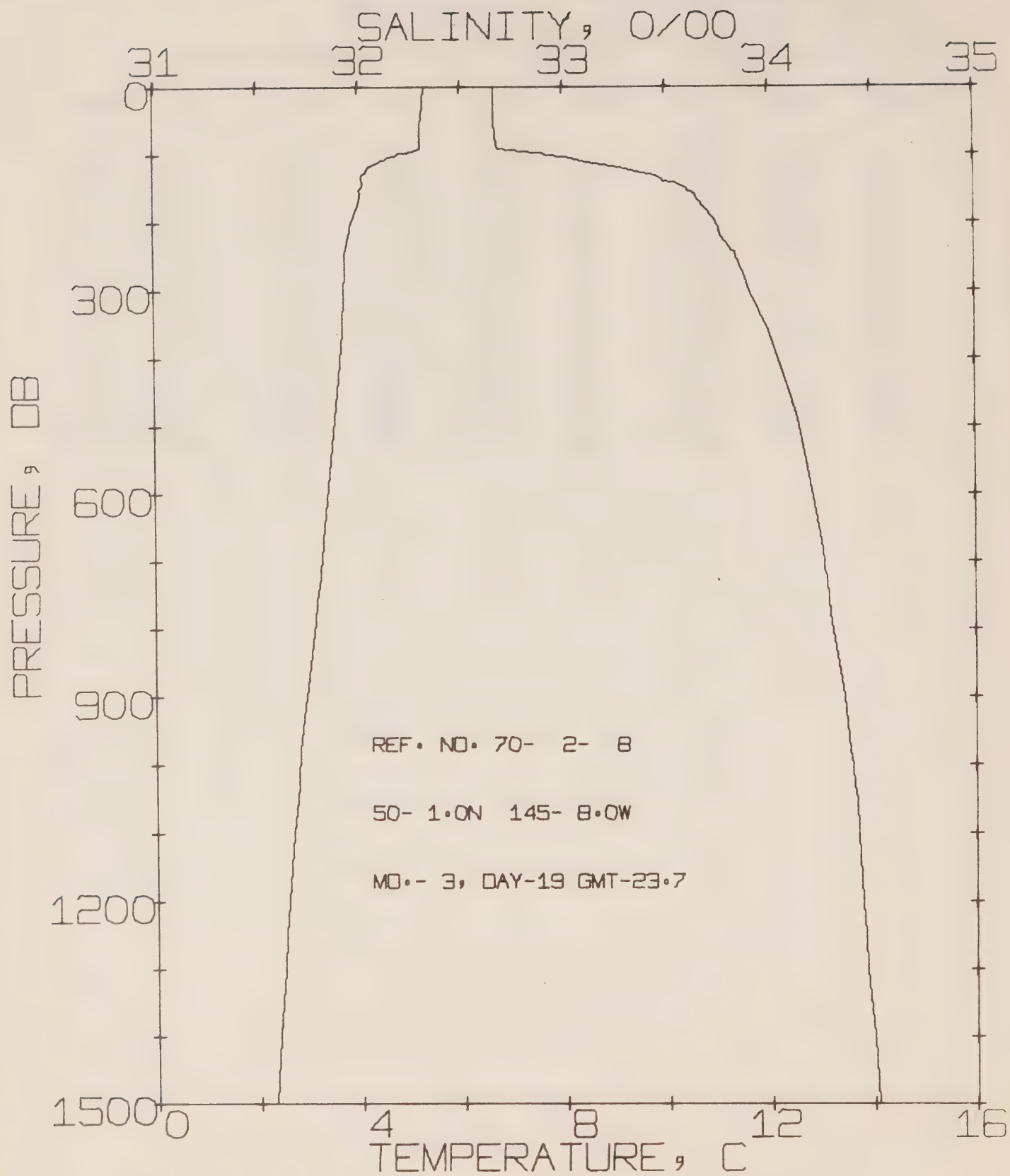
REFERENCE NO. 70- 2- 7

DATE 12/ 3/70

POSITION 50- 0.0N, 145- 0.0W GMT 19.0

RESULTS OF STP CAST 46 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.27	32.68	0	25.83	217.5	0.00	0.00	1469.
10	5.23	32.68	10	25.83	217.4	0.22	0.01	1469.
20	5.23	32.68	20	25.83	217.5	0.43	0.04	1469.
30	5.23	32.68	30	25.83	217.6	0.65	0.10	1469.
50	5.21	32.69	50	25.84	216.9	1.09	0.28	1470.
75	5.16	32.69	75	25.85	216.5	1.63	0.62	1470.
100	4.90	32.81	99	25.97	205.3	2.16	1.10	1469.
125	4.11	33.36	124	26.50	155.4	2.62	1.62	1467.
150	4.01	33.61	149	26.70	136.0	2.98	2.12	1467.
175	3.95	33.70	174	26.78	129.1	3.31	2.67	1468.
200	3.81	33.77	199	26.85	122.4	3.62	3.27	1468.
225	3.74	33.81	223	26.89	118.8	3.93	3.92	1468.
250	3.72	33.86	248	26.93	115.4	4.22	4.63	1468.
300	3.70	33.93	298	26.98	110.3	4.78	6.20	1469.



PACIFIC OCEANOGRAPHIC GROUP

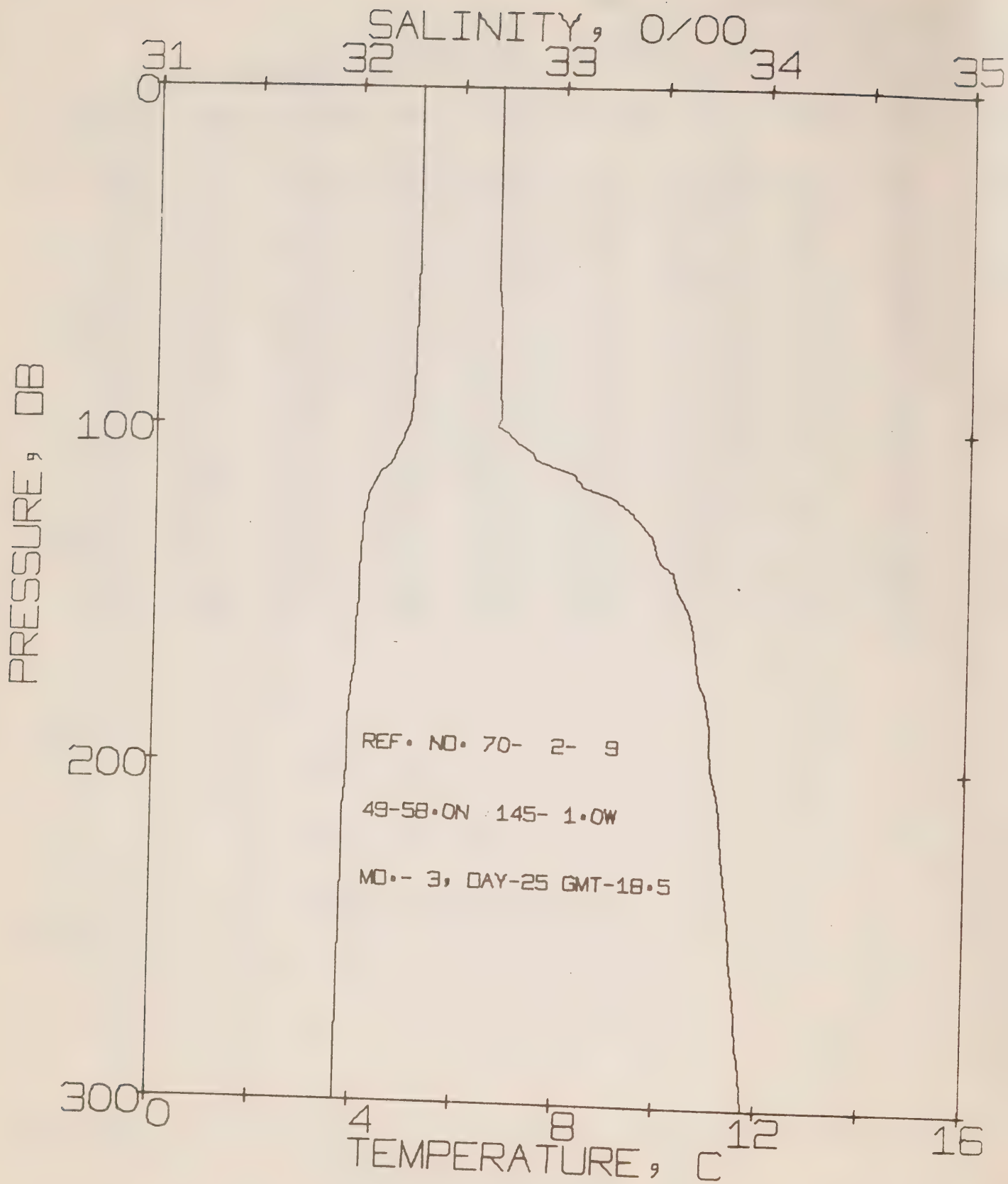
REFERENCE NO. 70- 2- 8

DATE 19/ 3/70

POSITION 50- 1.0N, 145- 8.0W GMT 23.7

RESULTS OF STP CAST 67 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.32	32.67	0	25.81	218.7	0.00	0.00	1469.
10	5.30	32.67	10	25.82	218.9	0.22	0.01	1469.
20	5.27	32.67	20	25.82	218.7	0.44	0.04	1469.
30	5.26	32.67	30	25.82	218.7	0.66	0.10	1469.
50	5.25	32.67	50	25.82	218.7	1.09	0.28	1470.
75	5.23	32.68	75	25.83	218.3	1.64	0.63	1470.
100	4.78	32.90	99	26.06	196.7	2.18	1.11	1469.
125	4.16	33.35	124	26.48	156.8	2.62	1.61	1467.
150	4.06	33.59	149	26.68	137.8	2.99	2.12	1468.
175	3.99	33.68	174	26.76	131.0	3.32	2.68	1468.
200	3.88	33.74	199	26.82	125.3	3.64	3.29	1468.
225	3.80	33.78	223	26.86	121.9	3.95	3.96	1468.
250	3.73	33.84	248	26.91	116.8	4.25	4.68	1468.
300	3.72	33.91	298	26.97	112.0	4.82	6.28	1469.
400	3.64	34.04	397	27.08	101.9	5.89	10.07	1471.
500	3.52	34.15	496	27.17	93.7	6.86	14.54	1472.
600	3.37	34.21	595	27.24	88.3	7.77	19.63	1473.
800	3.10	34.30	793	27.34	79.6	9.44	31.53	1475.
1000	2.80	34.40	990	27.44	70.7	10.94	45.21	1477.
1200	2.58	34.45	1188	27.50	65.6	12.30	60.40	1480.
1500	2.31	34.52	1483	27.58	58.9	14.16	86.01	1484.



PACIFIC OCEANOGRAPHIC GROUP

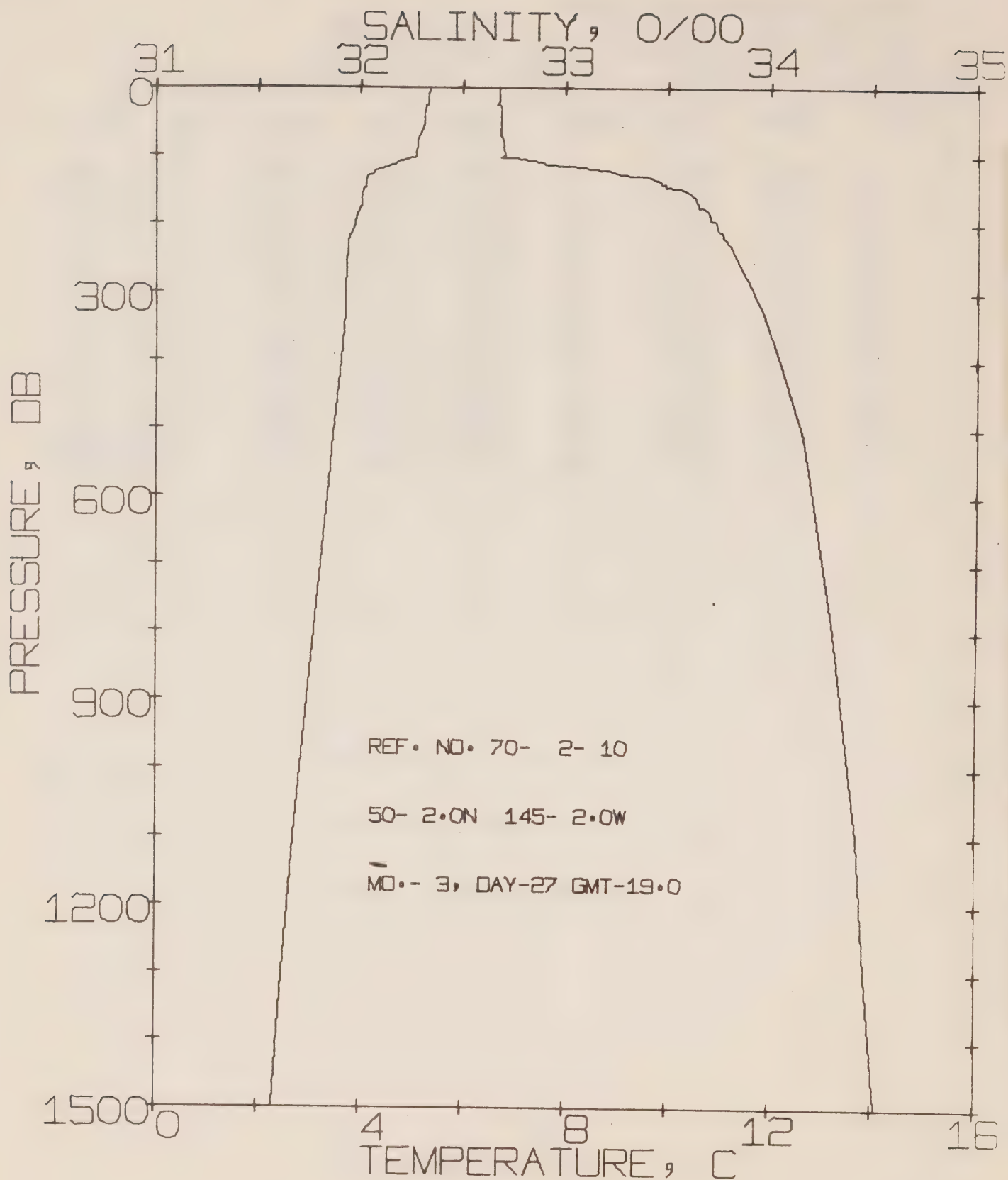
REFERENCE NO. 70- 2- 9

DATE 25/ 3/70

POSITION, 49-58.0N, 145- 1.0W GMT 18.5

RESULTS OF STP CAST 48 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.18	32.69	0	25.85	215.7	0.00	0.00	1469.
10	5.18	32.69	10	25.85	216.1	0.22	0.01	1469.
20	5.18	32.69	20	25.85	216.2	0.43	0.04	1469.
30	5.18	32.69	30	25.85	216.3	0.65	0.10	1469.
50	5.18	32.69	50	25.85	216.5	1.08	0.28	1469.
75	5.12	32.70	75	25.86	215.3	1.62	0.62	1470.
100	5.02	32.69	99	25.87	214.8	2.16	1.10	1470.
125	4.19	33.35	124	26.47	157.6	2.63	1.64	1467.
150	4.06	33.60	149	26.69	137.1	2.99	2.15	1468.
175	3.96	33.70	174	26.78	129.2	3.32	2.69	1468.
200	3.86	33.76	199	26.83	123.9	3.64	3.29	1468.
225	3.78	33.82	223	26.89	118.7	3.94	3.94	1468.
250	3.75	33.86	248	26.93	115.2	4.23	4.65	1468.
300	3.72	33.94	298	26.99	109.8	4.79	6.22	1469.



PACIFIC OCEANOGRAPHIC GROUP

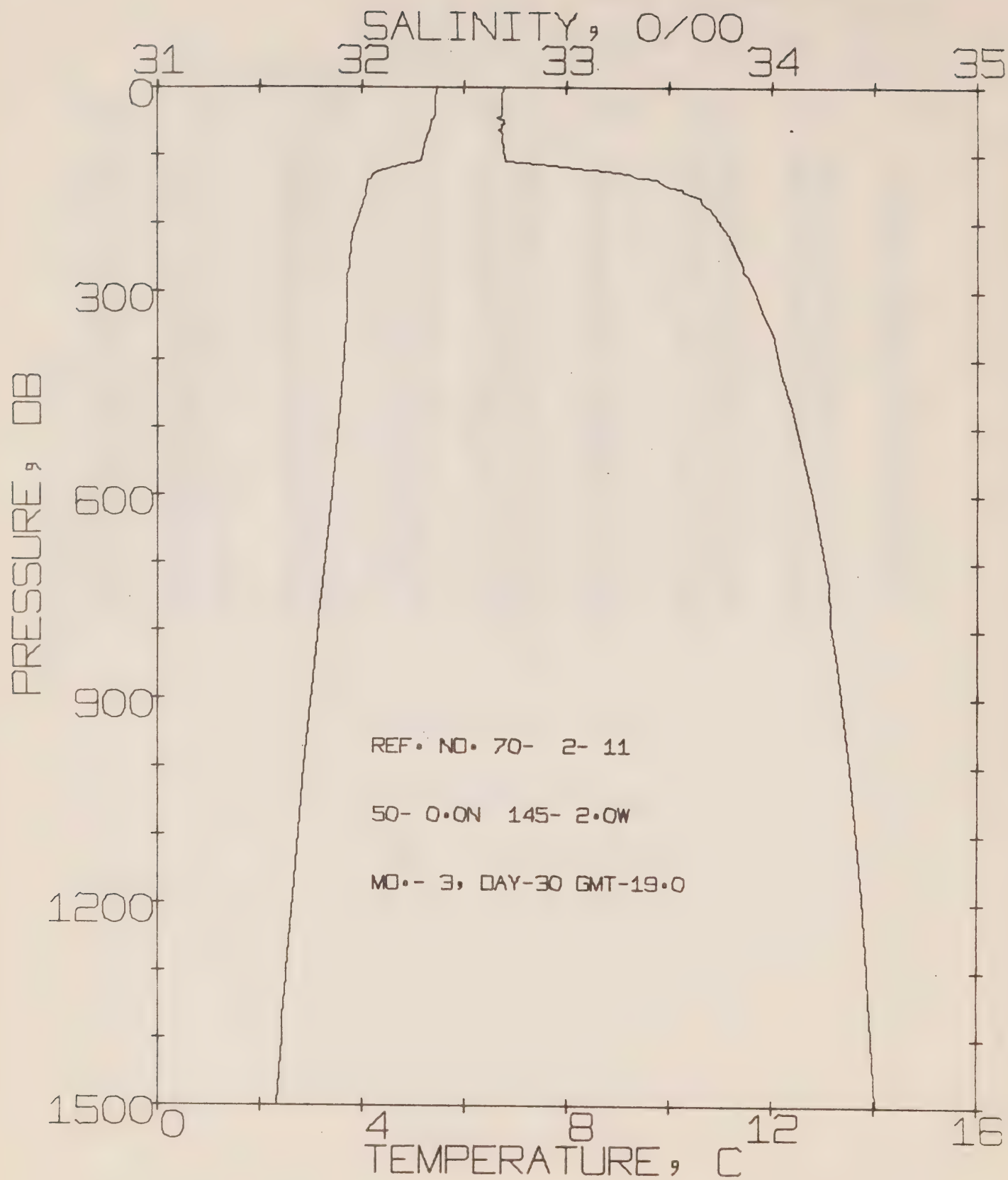
REFERENCE NO. 70- 2- 10

DATE 27/ 3/70

POSITION 50- 2.0N, 145- 2.0W GMT 19.0

RESULTS OF STP CAST 71 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.35	32.68	0	25.82	218.3	0.00	0.00	1469.
10	5.34	32.68	10	25.82	218.6	0.22	0.01	1469.
20	5.34	32.68	20	25.82	218.7	0.44	0.04	1470.
30	5.27	32.69	30	25.84	217.3	0.66	0.10	1470.
50	5.26	32.69	50	25.84	217.3	1.09	0.28	1470.
75	5.15	32.69	75	25.85	216.1	1.63	0.62	1470.
100	5.10	32.71	99	25.87	214.6	2.17	1.10	1470.
125	4.28	33.23	124	26.37	167.4	2.66	1.66	1468.
150	4.07	33.55	149	26.65	140.9	3.04	2.19	1468.
175	4.03	33.65	174	26.73	133.5	3.38	2.75	1468.
200	3.90	33.73	199	26.81	126.1	3.70	3.37	1468.
225	3.79	33.78	223	26.86	121.3	4.01	4.04	1468.
250	3.74	33.83	248	26.90	117.6	4.31	4.76	1468.
300	3.71	33.92	298	26.98	111.2	4.88	6.36	1469.
400	3.63	34.05	397	27.09	101.4	5.94	10.13	1471.
500	3.50	34.15	496	27.18	93.3	6.91	14.57	1472.
600	3.37	34.21	595	27.24	88.2	7.82	19.64	1473.
800	3.10	34.31	793	27.34	79.2	9.49	31.50	1475.
1000	2.84	34.39	990	27.43	71.8	11.00	45.28	1477.
1200	2.59	34.45	1188	27.50	65.8	12.37	60.58	1480.
1500	2.30	34.52	1483	27.58	58.9	14.24	86.23	1484.



PACIFIC OCEANOGRAPHIC GROUP

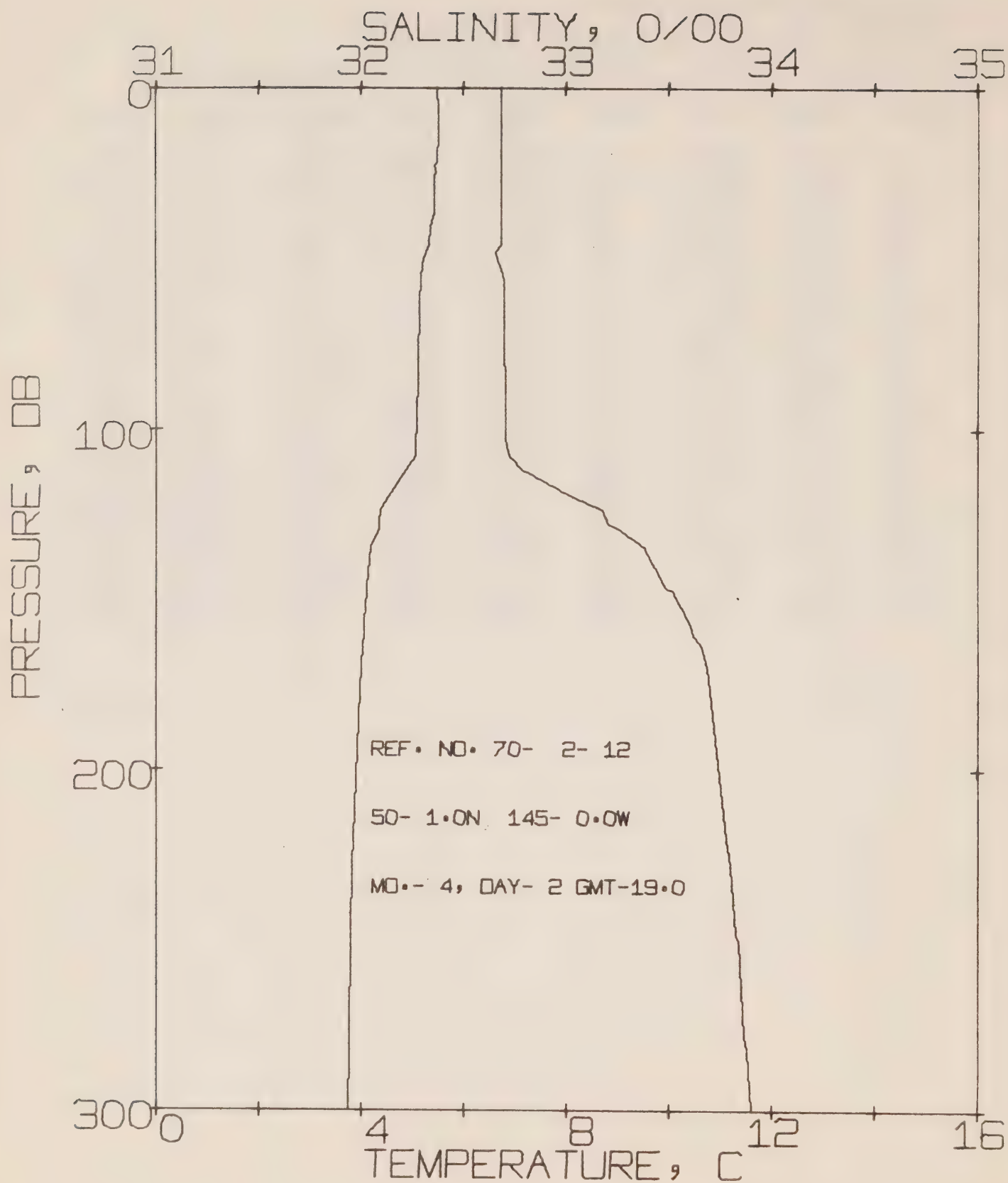
REFERENCE NO. 70- 2- 11

DATE 30/ 3/70

POSITION 50- 0.ON, 145- 2.OW GMT 19.0

RESULTS OF STP CAST 67 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.50	32.70	0	25.82	218.5	0.00	0.00	1470.
10	5.47	32.69	10	25.81	219.2	0.22	0.01	1470.
20	5.44	32.69	20	25.82	219.1	0.44	0.04	1470.
30	5.44	32.69	30	25.82	219.1	0.66	0.10	1470.
50	5.36	32.69	50	25.83	218.2	1.10	0.28	1470.
75	5.26	32.69	75	25.84	217.6	1.64	0.63	1470.
100	5.19	32.70	99	25.85	216.5	2.18	1.11	1470.
125	4.31	33.21	124	26.36	168.7	2.69	1.69	1468.
150	4.09	33.54	149	26.64	142.0	3.07	2.23	1468.
175	4.02	33.68	174	26.75	131.3	3.41	2.79	1468.
200	3.90	33.75	199	26.82	125.0	3.73	3.40	1468.
225	3.81	33.80	223	26.87	120.4	4.04	4.06	1468.
250	3.77	33.84	248	26.91	117.2	4.34	4.78	1468.
300	3.72	33.92	298	26.97	111.3	4.91	6.38	1469.
400	3.65	34.04	397	27.07	102.6	5.97	10.17	1471.
500	3.54	34.12	496	27.15	95.7	6.97	14.71	1472.
600	3.42	34.20	595	27.23	89.5	7.89	19.89	1473.
800	3.14	34.29	793	27.33	80.9	9.58	31.88	1475.
1000	2.87	34.38	990	27.42	72.8	11.11	45.92	1478.
1200	2.63	34.44	1188	27.49	66.8	12.51	61.51	1480.
1500	2.33	34.51	1484	27.57	59.9	14.41	87.52	1484.



PACIFIC OCEANOGRAPHIC GROUP

REFERENCE NO. 70- 2- 12

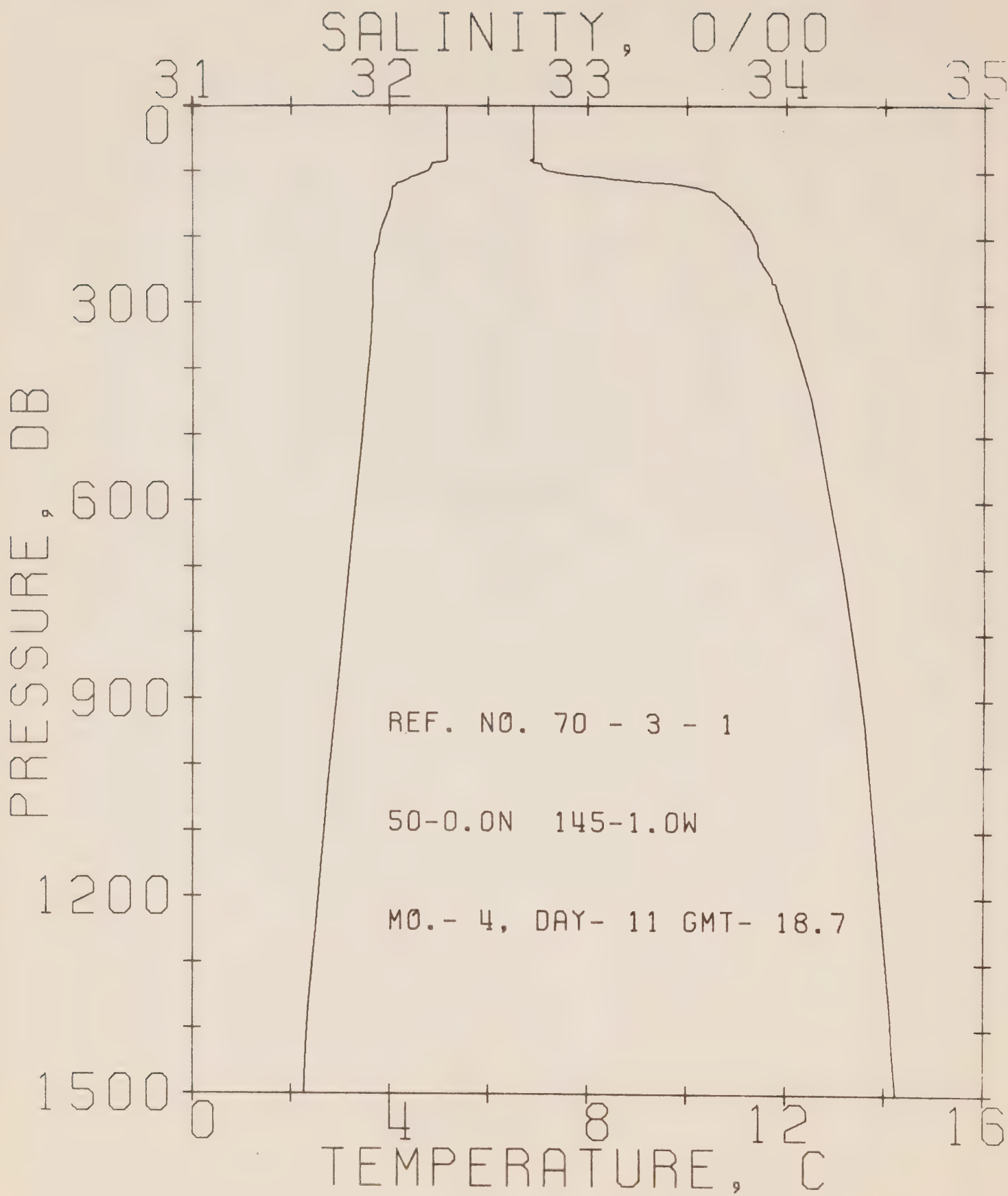
DATE 2/ 4/70

POSITION 50- 1.0N, 145- 0.0W GMT 19.0

RESULTS OF STP CAST 41 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.50	32.69	0	25.81	219.2	0.00	0.00	1470.
10	5.53	32.69	10	25.81	219.9	0.22	0.01	1470.
20	5.50	32.69	20	25.81	219.7	0.44	0.04	1470.
30	5.44	32.69	30	25.82	219.1	0.66	0.10	1470.
50	5.24	32.67	50	25.82	218.7	1.10	0.28	1470.
75	5.13	32.70	75	25.86	215.1	1.64	0.62	1470.
100	5.10	32.71	99	25.87	214.6	2.17	1.10	1470.
125	4.38	33.18	124	26.32	171.7	2.68	1.68	1468.
150	4.09	33.53	149	26.63	142.8	3.07	2.22	1468.
175	3.99	33.70	174	26.77	129.6	3.40	2.78	1468.
200	3.91	33.74	199	26.81	125.7	3.72	3.39	1468.
225	3.84	33.79	223	26.86	121.4	4.03	4.06	1468.
250	3.79	33.83	248	26.90	117.8	4.33	4.78	1468.
300	3.74	33.90	298	26.96	112.9	4.91	6.39	1469.

RESULTS OF STD CASTS
(P-70-3)



PACIFIC OCEANOGRAPHIC GROUP

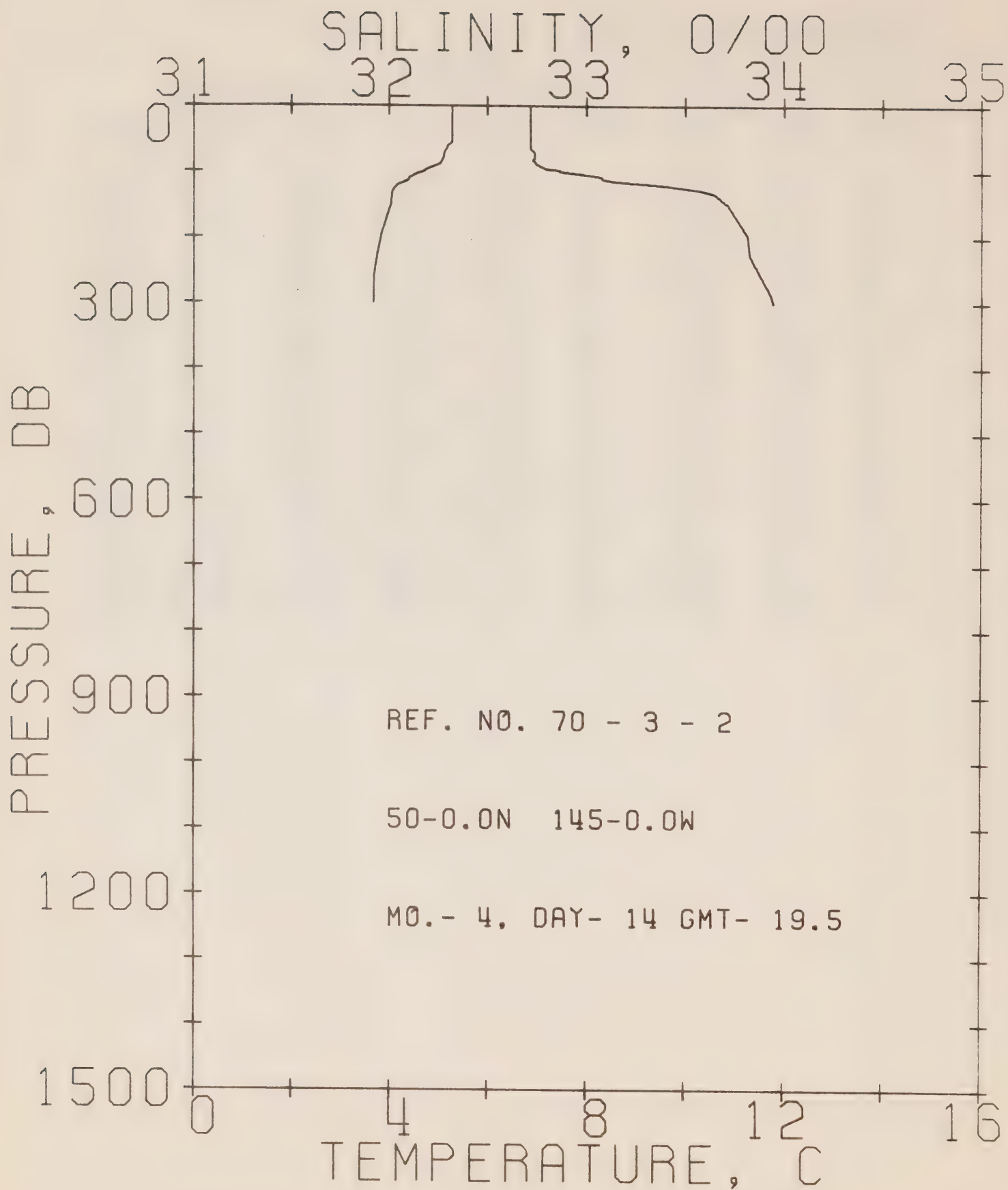
REFERENCE NO. 70- 3- 1

DATE 11/ 4/70

POSITION 50- 0.ON, 145- 1.OW GMT 18.7

RESULTS OF STP CAST 42 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.17	32.73	0	25.88	212.6	0.00	0.00	1469.
10	5.17	32.73	10	25.88	213.0	0.21	0.01	1469.
20	5.17	32.73	20	25.88	213.1	0.43	0.04	1469.
30	5.17	32.73	30	25.88	213.2	0.64	0.10	1469.
50	5.17	32.73	50	25.88	213.4	1.07	0.27	1470.
75	5.17	32.73	75	25.88	213.6	1.60	0.61	1470.
100	4.74	32.83	99	26.01	201.7	2.12	1.08	1469.
125	4.06	33.56	124	26.66	139.8	2.55	1.56	1467.
150	4.03	33.71	149	26.78	128.6	2.88	2.03	1468.
175	3.91	33.79	174	26.85	122.1	3.19	2.54	1468.
200	3.81	33.84	199	26.91	117.0	3.49	3.11	1468.
225	3.72	33.86	223	26.93	115.0	3.78	3.74	1468.
250	3.69	33.91	248	26.97	111.6	4.06	4.43	1468.
300	3.67	33.98	298	27.03	106.4	4.61	5.95	1469.
400	3.57	34.09	397	27.12	97.8	5.63	9.57	1470.
500	3.45	34.17	496	27.20	91.3	6.57	13.89	1472.
600	3.31	34.23	595	27.26	86.1	7.46	18.85	1473.
800	3.05	34.34	793	27.37	76.7	9.08	30.38	1475.
1000	2.80	34.42	990	27.46	69.0	10.53	43.64	1477.
1200	2.55	34.48	1188	27.53	63.3	11.85	58.43	1480.
1500	2.25	34.56	1483	27.62	55.5	13.62	82.74	1483.



PACIFIC OCEANOGRAPHIC GROUP

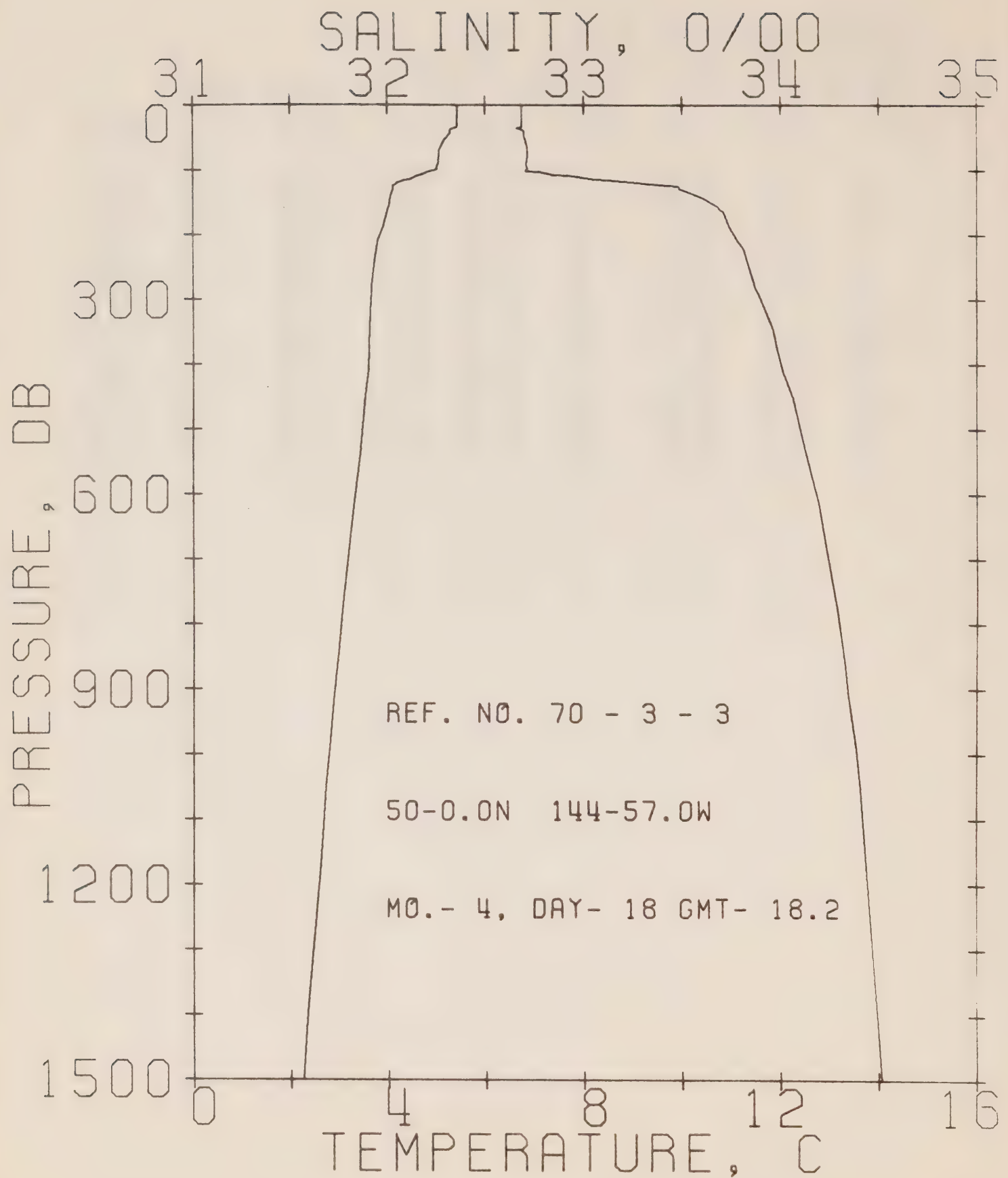
REFERENCE NO. 70- 3- 2

DATE 14/ 4/70

POSITION 50- 0.0N, 145- 0.0W GMT 19.5

RESULTS OF STP CAST 25 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.30	32.72	0	25.86	214.8	0.00	0.00	1469.
10	5.30	32.72	10	25.86	215.1	0.21	0.01	1469.
20	5.30	32.72	20	25.86	215.2	0.43	0.04	1470.
30	5.29	32.72	30	25.86	215.3	0.65	0.10	1470.
50	5.29	32.72	50	25.86	215.4	1.08	0.27	1470.
75	5.14	32.74	75	25.89	212.5	1.61	0.62	1470.
100	4.71	32.87	99	26.04	198.4	2.13	1.08	1469.
125	4.13	33.49	124	26.59	146.1	2.57	1.58	1467.
150	4.05	33.72	149	26.78	128.5	2.90	2.04	1468.
175	3.95	33.77	174	26.84	123.5	3.22	2.57	1468.
200	3.85	33.82	199	26.88	119.1	3.52	3.14	1468.
225	3.79	33.83	223	26.90	118.0	3.82	3.78	1468.
250	3.73	33.87	248	26.94	114.5	4.11	4.49	1468.
300	3.68	33.95	298	27.00	108.5	4.66	6.04	1469.



PACIFIC OCEANOGRAPHIC GROUP

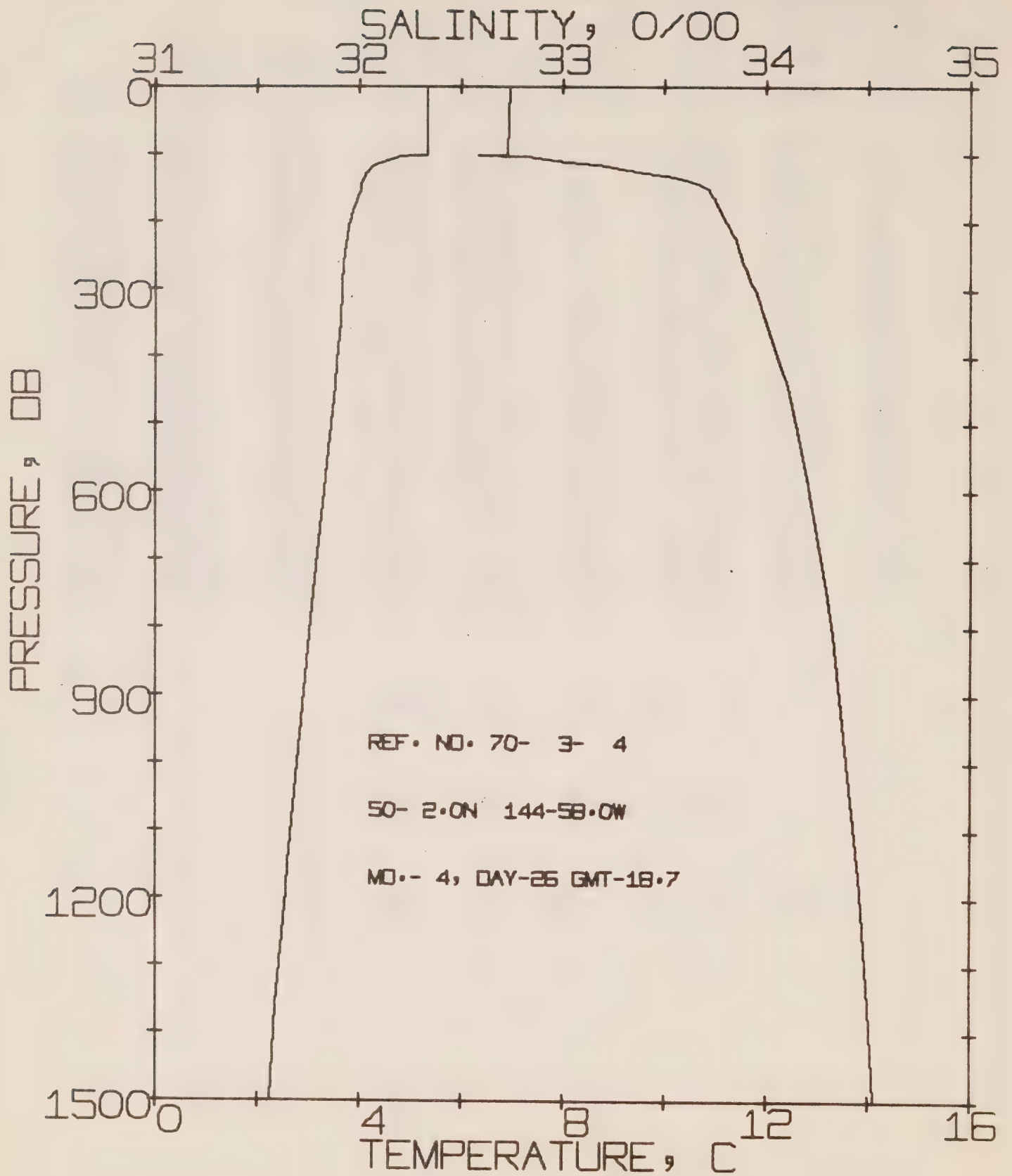
REFERENCE NO. 70- 3- 3

DATE 18/ 4/70

POSITION 50- 0.0N, 144-57.0W GMT 18.2

RESULTS OF STP CAST 51 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.46	32.69	0	25.81	218.8	0.00	0.00	1470.
10	5.45	32.69	10	25.82	219.1	0.22	0.01	1470.
20	5.45	32.69	20	25.82	219.1	0.44	0.04	1470.
30	5.44	32.69	30	25.82	219.2	0.66	0.10	1470.
50	5.23	32.71	50	25.85	215.7	1.09	0.28	1470.
75	5.08	32.72	75	25.88	213.5	1.63	0.62	1470.
100	4.99	32.71	99	25.88	213.4	2.16	1.10	1470.
125	4.14	33.48	124	26.59	146.6	2.62	1.62	1467.
150	4.06	33.65	149	26.73	133.5	2.97	2.11	1468.
175	3.98	33.73	174	26.80	126.8	3.29	2.64	1468.
200	3.87	33.77	199	26.84	123.0	3.61	3.24	1468.
225	3.79	33.82	223	26.89	118.5	3.91	3.89	1468.
250	3.75	33.85	248	26.92	116.3	4.20	4.60	1468.
300	3.68	33.91	298	26.97	111.6	4.77	6.20	1469.
400	3.63	34.01	397	27.06	104.2	5.85	10.03	1470.
500	3.51	34.11	496	27.15	96.4	6.85	14.60	1472.
600	3.35	34.19	595	27.23	89.5	7.78	19.82	1473.
800	3.07	34.30	793	27.34	79.4	9.46	31.79	1475.
1000	2.80	34.39	990	27.44	71.1	10.97	45.57	1477.
1200	2.59	34.45	1188	27.50	66.0	12.34	60.88	1480.
1500	2.28	34.52	1483	27.58	58.6	14.20	86.47	1484.



PACIFIC OCEANOGRAPHIC GROUP

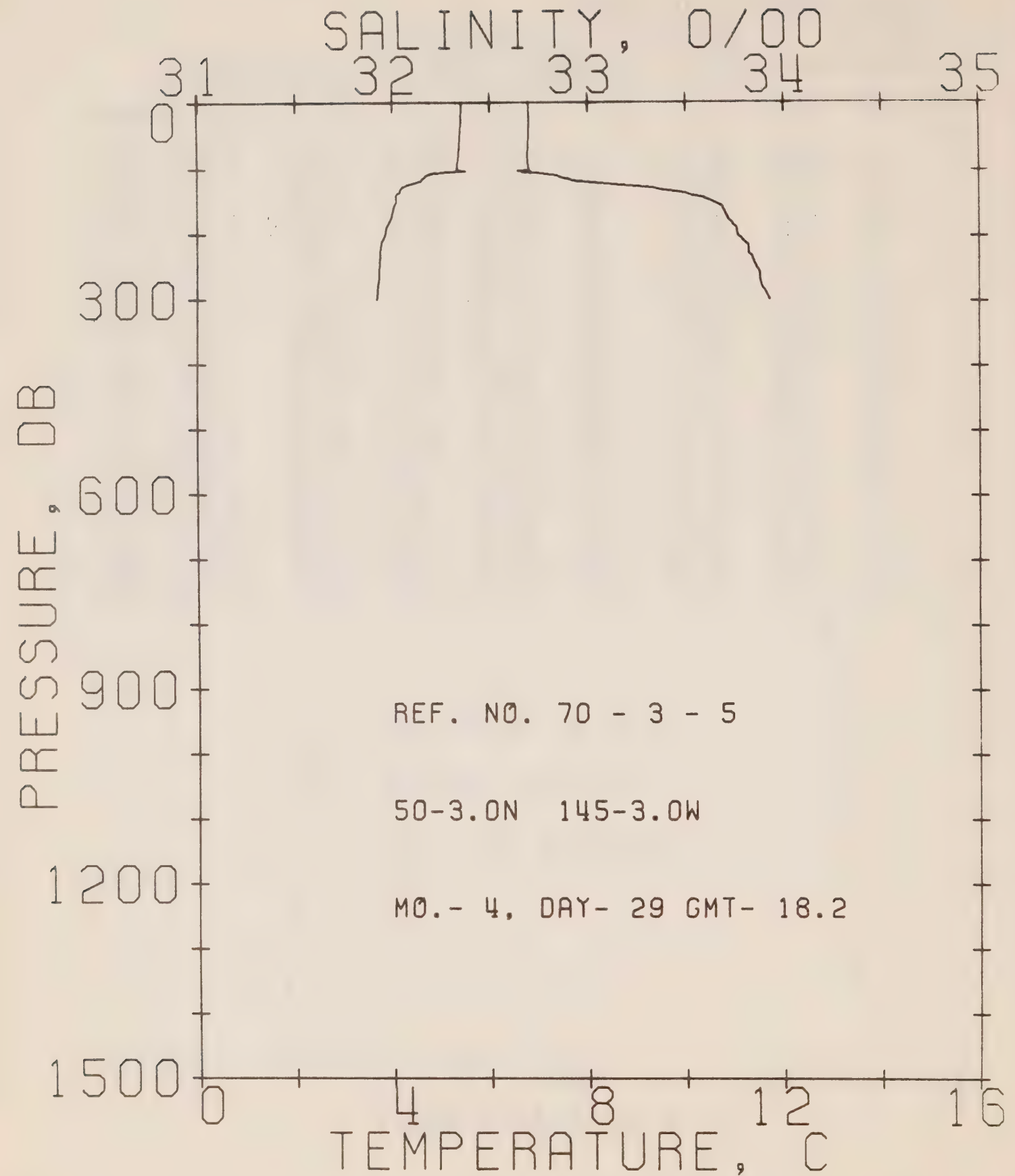
REFERENCE NO. 70- 3- 4

DATE 26/ 4/70

POSITION 50- 2.0N, 144-58.0W GMT 18.7

RESULTS OF STP CAST 40 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.34	32.74	0	25.87	213.7	0.00	0.00	1469.
10	5.34	32.74	10	25.87	214.2	0.21	0.01	1470.
20	5.34	32.74	20	25.87	214.3	0.43	0.04	1470.
30	5.34	32.74	30	25.87	214.5	0.64	0.10	1470.
50	5.34	32.74	50	25.86	214.8	1.07	0.27	1470.
75	5.34	32.73	75	25.86	215.3	1.61	0.62	1471.
100	5.34	32.73	99	25.86	215.7	2.15	1.10	1471.
125	4.18	33.35	124	26.48	157.1	2.62	1.63	1467.
150	4.02	33.70	149	26.77	129.3	2.97	2.12	1468.
175	3.93	33.76	174	26.82	124.6	3.28	2.64	1468.
200	3.81	33.80	199	26.87	120.4	3.59	3.23	1468.
225	3.75	33.85	223	26.92	116.0	3.89	3.87	1468.
250	3.71	33.88	248	26.94	113.9	4.17	4.56	1468.
300	3.65	33.95	298	27.00	108.4	4.73	6.12	1469.
400	3.57	34.06	397	27.10	100.1	5.77	9.84	1470.
500	3.45	34.15	496	27.18	93.0	6.74	14.24	1472.
600	3.31	34.21	595	27.25	87.4	7.64	19.29	1473.
800	3.02	34.32	793	27.36	77.3	9.28	30.96	1475.
1000	2.78	34.40	990	27.44	70.6	10.76	44.47	1477.
1200	2.55	34.46	1188	27.52	64.3	12.10	59.51	1480.
1500	2.25	34.53	1483	27.59	57.5	13.93	84.53	1483.



PACIFIC OCEANOGRAPHIC GROUP

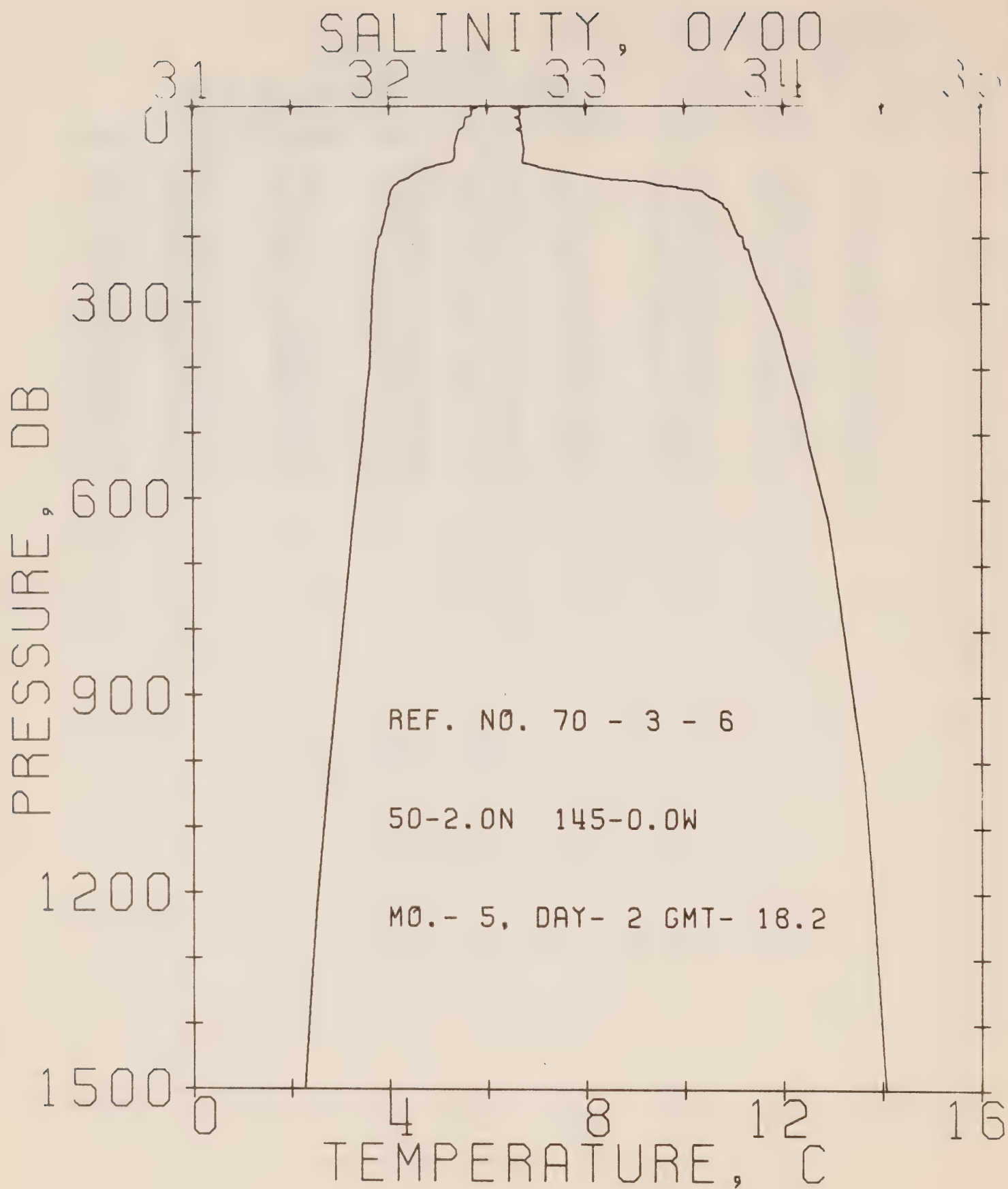
REFERENCE NO. 70- 3- 5

DATE 29/ 4/70

POSITION 50- 3.0N, 145- 3.0W GMT 18.2

RESULTS OF STP CAST 36 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.45	32.70	0	25.82	217.9	0.00	0.00	1470.
10	5.43	32.70	10	25.83	218.1	0.22	0.01	1470.
20	5.42	32.70	20	25.83	218.1	0.44	0.04	1470.
30	5.42	32.70	30	25.83	218.2	0.65	0.10	1470.
50	5.40	32.70	50	25.83	218.4	1.09	0.28	1470.
75	5.37	32.69	75	25.83	218.7	1.64	0.63	1471.
100	5.32	32.70	99	25.84	217.9	2.18	1.11	1471.
125	4.31	33.15	124	26.30	173.5	2.68	1.68	1468.
150	4.08	33.63	149	26.71	135.3	3.06	2.20	1468.
175	3.98	33.72	174	26.79	128.1	3.38	2.74	1468.
200	3.86	33.77	199	26.84	123.1	3.70	3.34	1468.
225	3.76	33.82	223	26.89	118.4	4.00	3.99	1468.
250	3.73	33.86	248	26.93	115.2	4.29	4.70	1468.
300	3.67	33.93	298	26.99	110.0	4.85	6.28	1469.



PACIFIC OCEANOGRAPHIC GROUP

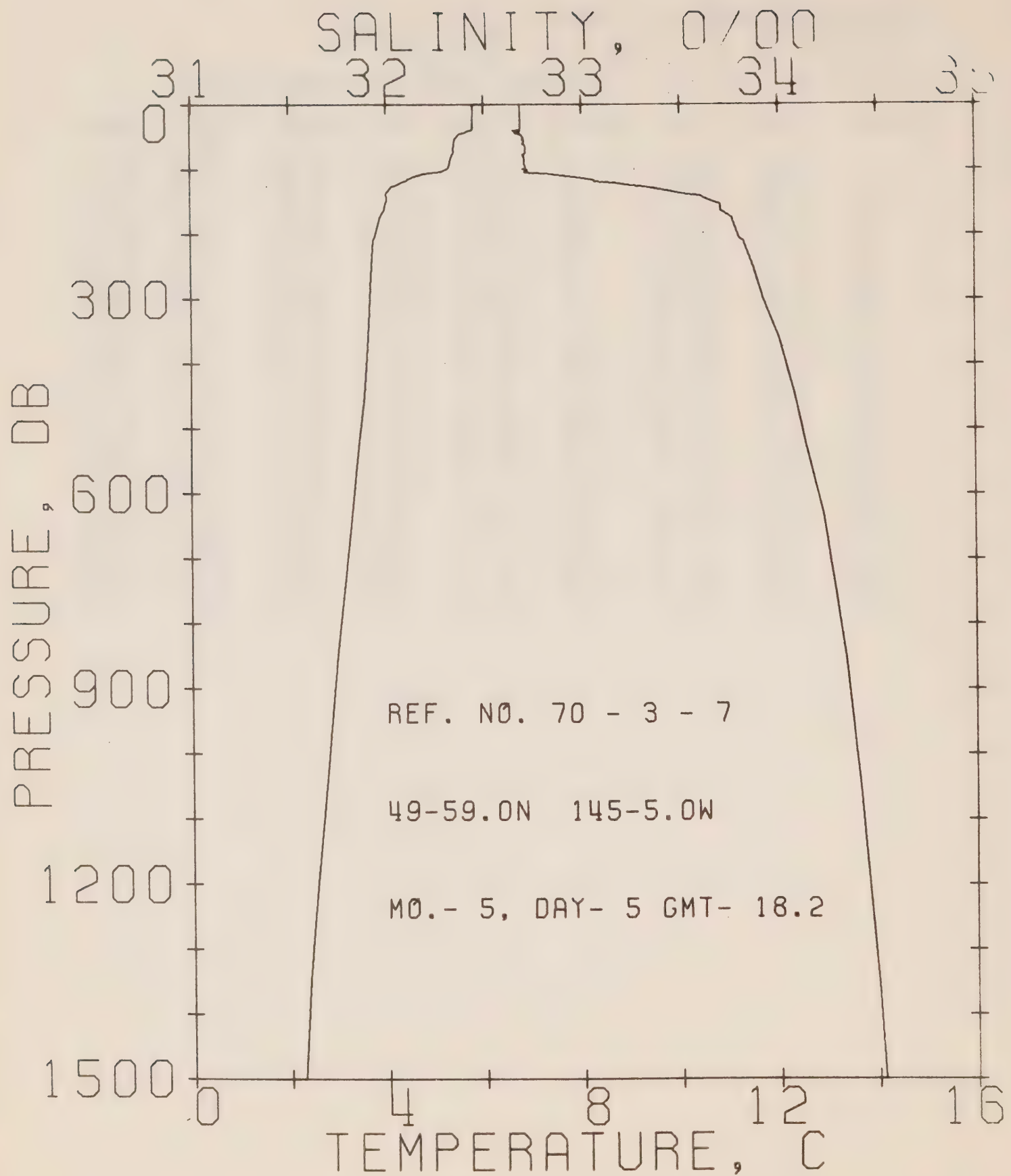
REFERENCE NO. 70- 3- 6

DATE 2/ 5/70

POSITION 50- 2.0N, 145- 0.0W GMT 18.2

RESULTS OF STP CAST 49 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.73	32.68	0	25.77	222.6	0.00	0.00	1471.
10	5.70	32.67	10	25.77	223.3	0.22	0.01	1471.
20	5.58	32.67	20	25.79	222.0	0.45	0.05	1471.
30	5.55	32.68	30	25.79	221.3	0.67	0.10	1471.
50	5.40	32.68	50	25.82	219.3	1.11	0.28	1470.
75	5.35	32.68	75	25.82	219.1	1.66	0.63	1471.
100	4.63	32.88	99	26.06	196.8	2.19	1.10	1468.
125	4.10	33.47	124	26.58	147.3	2.62	1.59	1467.
150	4.00	33.70	149	26.77	129.2	2.96	2.07	1468.
175	3.92	33.75	174	26.82	125.1	3.28	2.59	1468.
200	3.81	33.79	199	26.87	120.7	3.58	3.18	1468.
225	3.75	33.83	223	26.91	117.2	3.88	3.83	1468.
250	3.71	33.86	248	26.93	115.3	4.17	4.53	1468.
300	3.66	33.93	298	26.99	109.9	4.74	6.11	1469.
400	3.60	34.04	397	27.08	101.8	5.79	9.86	1470.
500	3.46	34.12	496	27.16	94.9	6.77	14.35	1472.
600	3.32	34.20	595	27.24	88.1	7.69	19.47	1473.
800	3.05	34.31	793	27.35	78.8	9.35	31.26	1475.
1000	2.78	34.40	990	27.44	70.4	10.84	44.87	1477.
1200	2.54	34.45	1188	27.51	64.8	12.19	59.95	1480.
1500	2.26	34.52	1483	27.59	58.4	14.04	85.24	1483.



PACIFIC OCEANOGRAPHIC GROUP

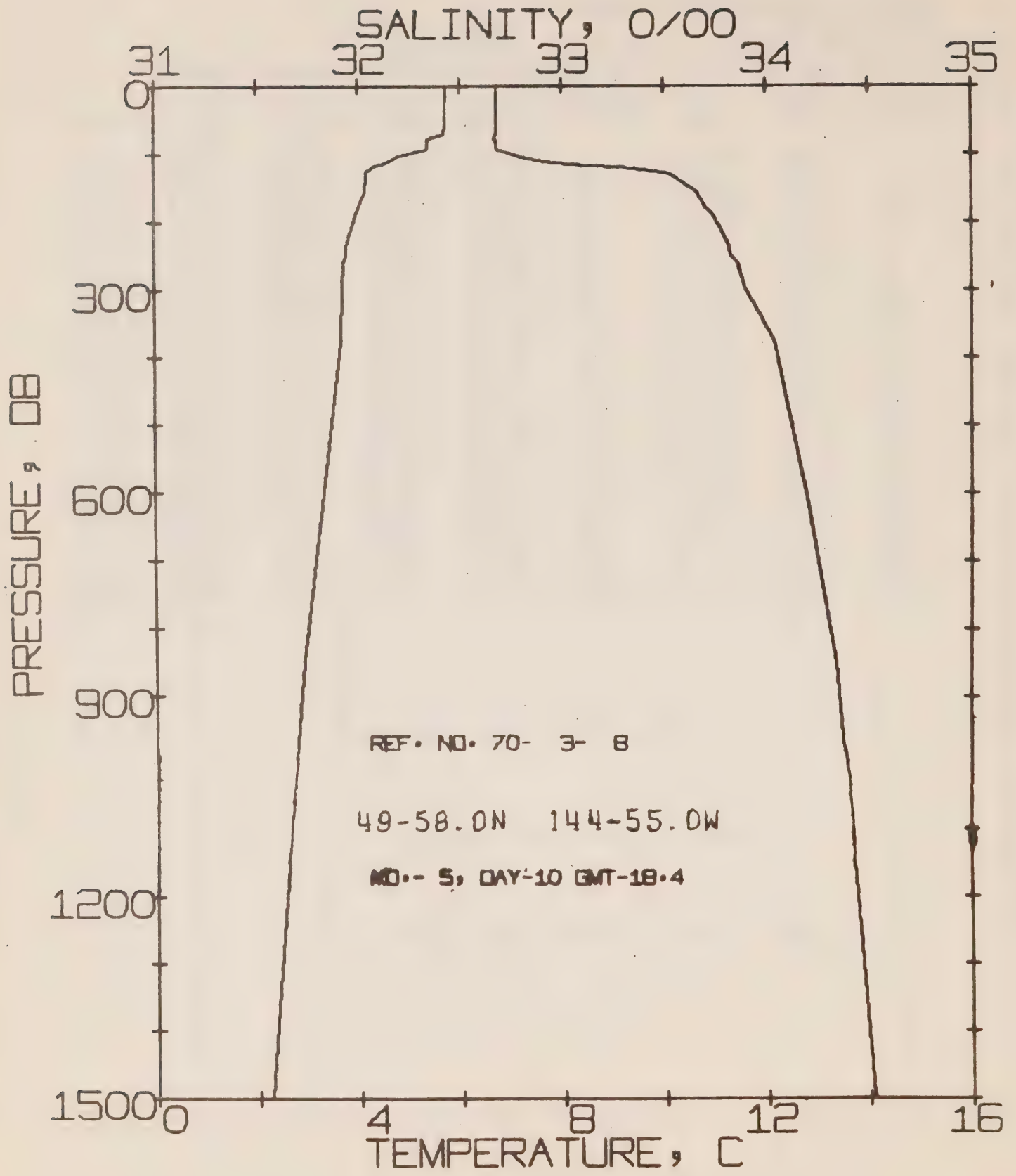
REFERENCE NO. 70- 3- 7

DATE 5/ 5/70

POSITION 49-59.0N, 145- 5.0W GMT 18.2

RESULTS OF STP CAST 55 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.80	32.69	0	25.77	222.6	0.00	0.00	1471.
10	5.80	32.69	10	25.77	223.0	0.22	0.01	1471.
20	5.79	32.69	20	25.77	223.0	0.45	0.05	1472.
30	5.79	32.69	30	25.78	223.1	0.67	0.10	1472.
50	5.47	32.71	50	25.83	218.3	1.11	0.28	1471.
75	5.40	32.71	75	25.84	217.4	1.66	0.63	1471.
100	5.25	32.72	99	25.86	215.8	2.20	1.11	1471.
125	4.21	33.27	124	26.41	163.1	2.68	1.66	1467.
150	4.03	33.67	149	26.75	131.5	3.04	2.16	1468.
175	3.90	33.77	174	26.84	123.2	3.35	2.69	1468.
200	3.80	33.80	199	26.87	120.0	3.66	3.27	1468.
225	3.74	33.85	223	26.92	116.1	3.95	3.90	1468.
250	3.71	33.88	248	26.94	113.7	4.24	4.60	1468.
300	3.67	33.93	298	26.99	110.0	4.80	6.16	1469.
400	3.60	34.04	397	27.09	101.3	5.85	9.91	1470.
500	3.48	34.12	496	27.16	94.8	6.83	14.40	1472.
600	3.33	34.20	595	27.24	88.2	7.75	19.52	1473.
800	3.05	34.31	793	27.35	78.4	9.41	31.29	1475.
1000	2.80	34.39	990	27.44	71.1	10.90	44.92	1477.
1200	2.55	34.45	1188	27.51	65.0	12.26	60.13	1480.



PACIFIC OCEANOGRAPHIC GROUP

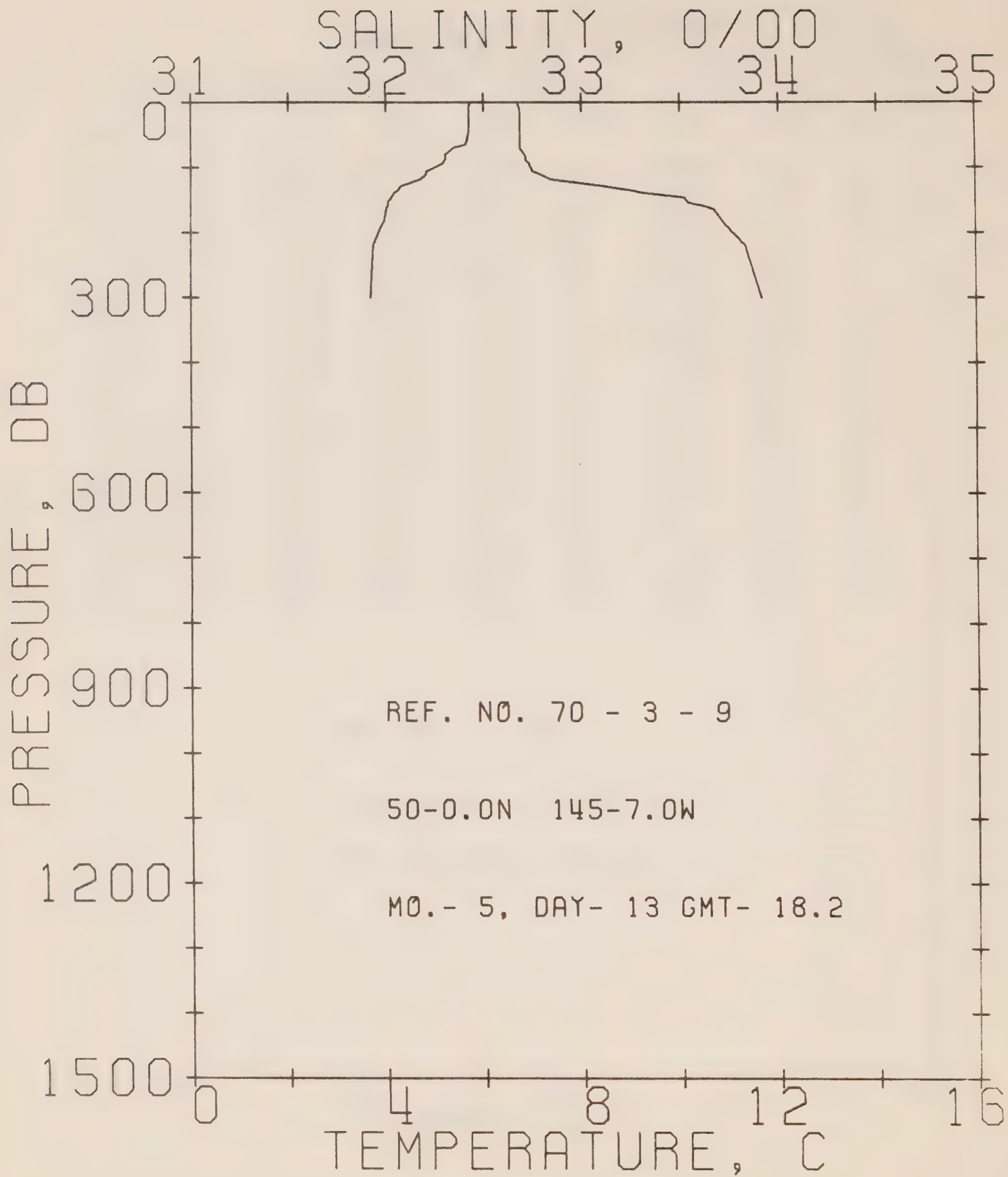
REFERENCE NO. 70- 3- 8

DATE 10/ 5/70

POSITION 49-58.0N, 144-55.0W GMT 18.4

RESULTS OF STP CAST 26 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.71	32.68	0	25.78	222.3	0.00	0.00	1471.
10	5.71	32.68	10	25.78	222.7	0.22	0.01	1471.
20	5.71	32.68	20	25.78	222.8	0.45	0.05	1471.
30	5.71	32.68	30	25.78	222.9	0.67	0.10	1471.
50	5.71	32.68	50	25.78	223.1	1.11	0.28	1472.
75	5.60	32.68	75	25.79	222.4	1.67	0.64	1472.
100	5.08	32.74	99	25.89	212.5	2.22	1.13	1470.
125	4.22	33.40	124	26.51	153.7	2.69	1.67	1468.
150	4.14	33.63	149	26.70	136.1	3.05	2.16	1468.
175	4.03	33.70	174	26.77	129.9	3.38	2.71	1468.
200	3.91	33.76	199	26.83	124.4	3.69	3.32	1468.
225	3.81	33.80	223	26.87	120.4	4.00	3.98	1468.
250	3.75	33.83	248	26.90	117.8	4.30	4.70	1468.
300	3.69	33.90	298	26.96	112.4	4.87	6.30	1469.
400	3.62	34.06	397	27.09	100.6	5.93	10.06	1470.
500	3.47	34.13	496	27.16	94.7	6.91	14.52	1472.
600	3.32	34.19	595	27.23	88.8	7.82	19.65	1473.
800	2.99	34.31	793	27.36	78.0	9.49	31.45	1475.
1000	2.75	34.39	990	27.44	71.0	10.97	45.00	1477.
1200	2.55	34.44	1188	27.50	65.8	12.34	60.30	1480.
1500	2.24	34.52	1483	27.59	58.2	14.20	85.72	1483.



PACIFIC OCEANOGRAPHIC GROUP

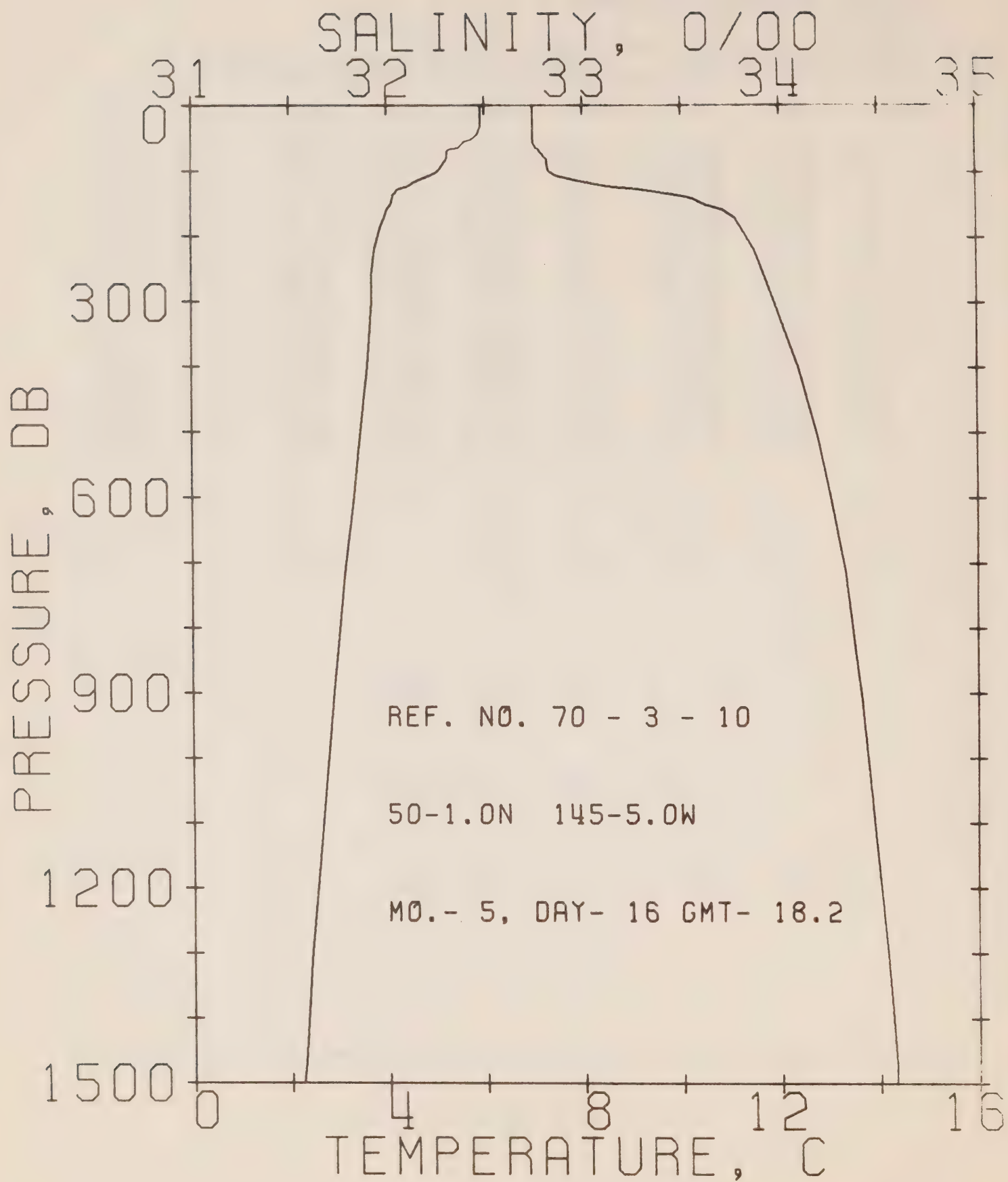
REFERENCE NO. 70- 3- 9

DATE 13/ 5/70

POSITION 50- 0.ON, 145- 7.OW GMT 18.2

RESULTS OF STP CAST 23 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.75	32.68	0	25.77	222.8	0.00	0.00	1471.
10	5.72	32.69	10	25.78	222.1	0.22	0.01	1471.
20	5.72	32.69	20	25.78	222.2	0.44	0.05	1471.
30	5.72	32.69	30	25.78	222.3	0.67	0.10	1471.
50	5.71	32.69	50	25.78	222.4	1.11	0.28	1472.
75	5.34	32.70	75	25.84	217.4	1.66	0.64	1471.
100	5.03	32.75	99	25.91	210.8	2.20	1.11	1470.
125	4.49	33.02	124	26.18	185.3	2.71	1.69	1468.
150	4.10	33.54	149	26.64	142.4	3.11	2.26	1468.
175	4.00	33.71	174	26.78	129.1	3.45	2.81	1468.
200	3.87	33.77	199	26.85	122.7	3.76	3.42	1468.
225	3.75	33.84	223	26.91	116.5	4.06	4.06	1468.
250	3.72	33.87	248	26.94	114.6	4.35	4.76	1468.
300	3.68	33.92	298	26.98	110.8	4.91	6.34	1469.



PACIFIC OCEANOGRAPHIC GROUP

REFERENCE NO. 70- 3- 10

DATE 16/ 5/70

POSITION 50- 1.0N, 145- 5.0W GMT 18.2

RESULTS OF STP CAST 32 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.93	32.75	0	25.81	219.6	0.00	0.00	1472.
10	5.93	32.75	10	25.81	220.0	0.22	0.01	1472.
20	5.93	32.75	20	25.81	220.1	0.44	0.04	1472.
30	5.93	32.75	30	25.81	220.2	0.66	0.10	1472.
50	5.79	32.75	50	25.82	218.8	1.10	0.28	1472.
75	5.26	32.80	75	25.93	209.0	1.63	0.62	1470.
100	5.06	32.84	99	25.98	204.4	2.15	1.08	1470.
125	4.34	33.22	124	26.36	168.5	2.63	1.63	1468.
150	4.11	33.62	149	26.70	136.0	3.00	2.14	1468.
175	3.96	33.79	174	26.85	122.3	3.32	2.67	1468.
200	3.84	33.84	199	26.90	117.6	3.62	3.24	1468.
225	3.75	33.88	223	26.94	113.5	3.90	3.86	1468.
250	3.72	33.92	248	26.97	111.0	4.18	4.54	1468.
300	3.69	33.98	298	27.03	106.4	4.73	6.06	1469.
400	3.60	34.10	397	27.13	97.4	5.75	9.68	1470.
500	3.46	34.19	496	27.21	90.0	6.68	13.95	1472.
600	3.32	34.26	595	27.28	84.0	7.55	18.82	1473.
800	3.02	34.37	793	27.40	74.1	9.12	29.98	1475.
1000	2.78	34.44	990	27.48	67.2	10.53	42.87	1477.
1200	2.54	34.51	1188	27.55	61.0	11.82	57.19	1480.
1500	2.24	34.58	1483	27.64	53.7	13.52	80.60	1483.

SURFACE TEMPERATURE AND SALINITY OBSERVATIONS

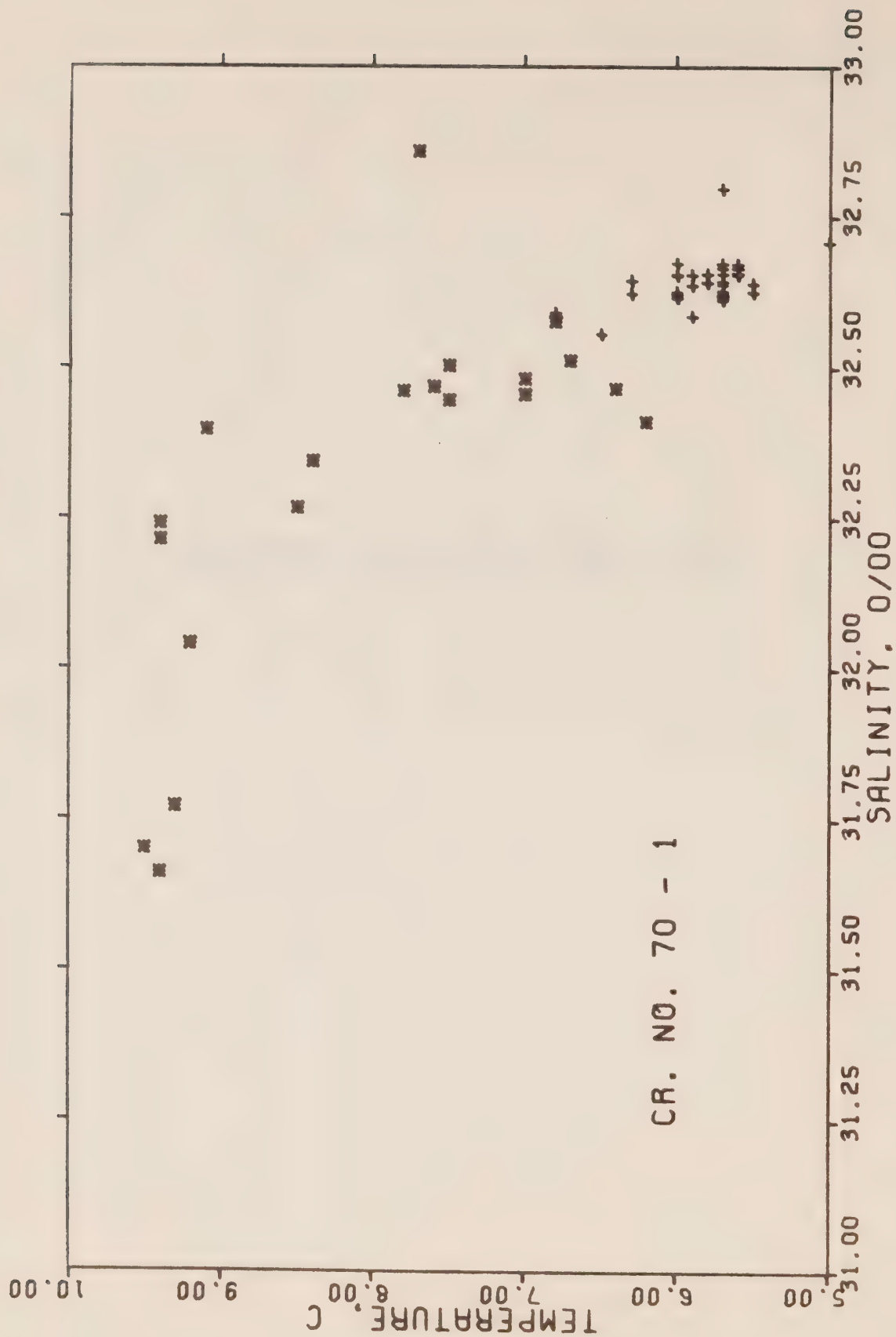


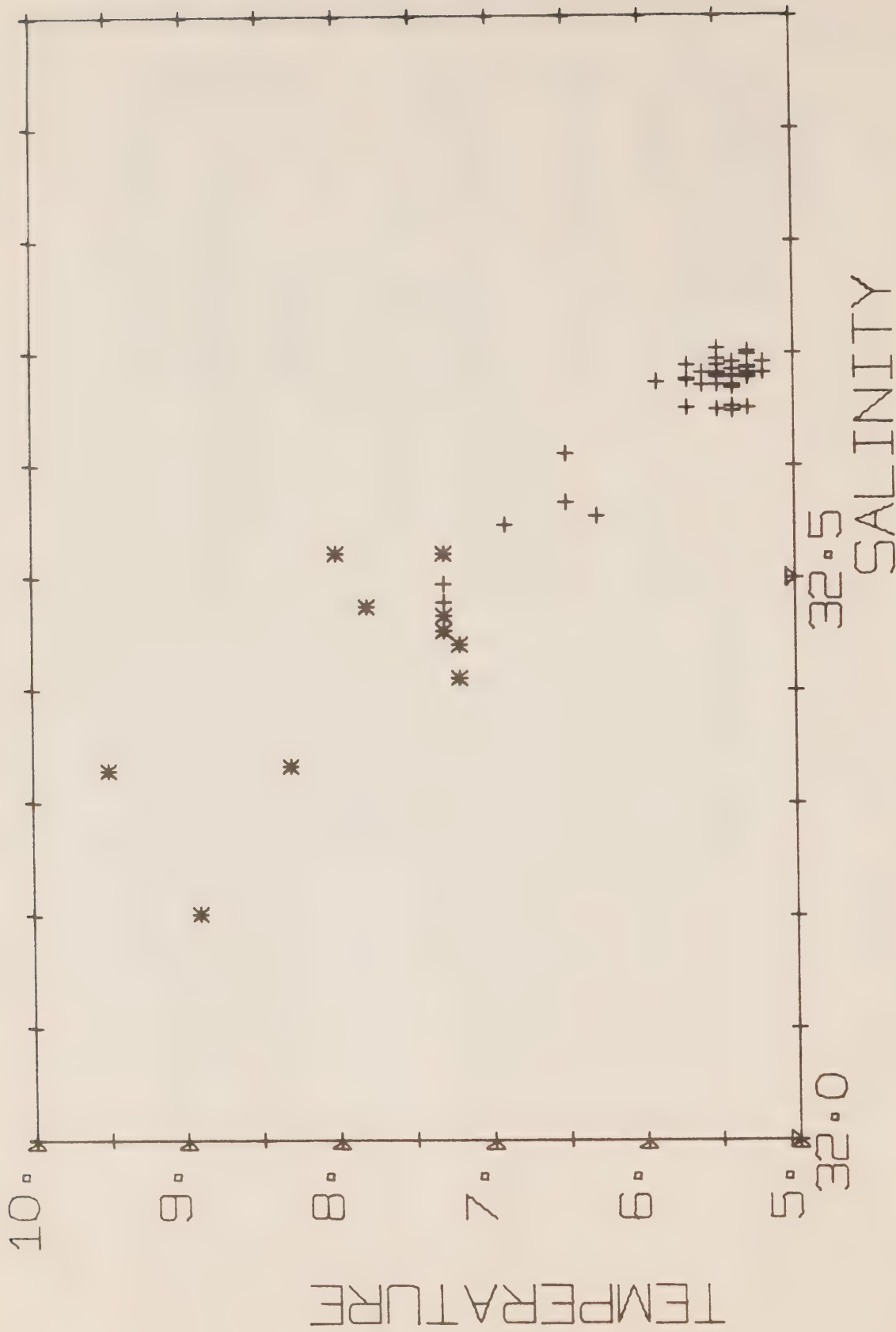
Fig. 6 T-S plot of surface temperature and salinity observations on Line P (asterisks) and at Station P (pluses) during Cruise P-70-1.

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 70- 1

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DY	GMT	0/00	C	WEST
70	1	10	130	32.859	7.7	125-32
70	1	10	350	32.212	9.4	126- 0
70	1	10	540	32.396	9.1	126-40
70	1	10	925	32.266	8.5	127-40
70	1	10	1330	32.344	8.4	128-40
70	1	10	1720	32.461	7.8	129-40
70	1	10	2030	32.483	7.0	130-40
70	1	11	15	32.480		131-40
70	1	11	340	32.466	6.4	132-40
70	1	11	710	32.411	6.2	133-40
70	1	11	1010	32.446	7.5	134-40
70	1	11	1420	32.469	7.6	135-40
70	1	11	1710	32.456	7.0	136-40
70	1	11	2040	32.513	6.7	137-40
70	1	11	2345	32.504	7.5	138-40
70	1	12	330	32.540		139-42
70	1	12	620	32.578	6.8	140-40
70	1	12	1010	32.556	6.5	141-40
70	1	12	1500	32.591	6.8	142-39
70	1	12	2025	32.624	6.3	143-40
70	1	13	0	32.626	6.0	ON STATION
70	1	14	0	32.626	5.5	ON STATION
70	1	15	0	32.617	6.0	ON STATION
70	1	16	0	32.655	6.0	ON STATION
70	1	22	0		6.0	ON STATION
70	1	23	0	32.645	6.3	ON STATION
70	1	24	0	32.642	5.8	ON STATION
70	1	25	0	32.622	6.0	ON STATION
70	1	26	0	32.617	5.7	ON STATION
70	1	30	0	32.655	5.6	ON STATION
70	1	31	0	32.663		ON STATION
70	2	1	0	32.660		ON STATION
70	2	2	0	32.586	5.9	ON STATION
70	2	3	0	32.709	5.0	ON STATION
70	2	4	0	32.656	5.7	ON STATION
70	2	5	0	32.798	5.7	ON STATION
70	2	6	0	32.644	5.7	ON STATION
70	2	7	0	32.674	6.0	ON STATION
70	2	8	0	32.637	5.9	ON STATION
70	2	9	0	32.640	5.5	ON STATION
70	2	10	0	32.628	5.7	ON STATION
70	2	11	0	32.623	5.7	ON STATION
70	2	12	300	32.656	5.8	ON STATION
70	2	13	0	32.621	5.7	ON STATION
70	2	14	0	32.614	5.7	ON STATION
70	2	15	0	32.666	5.7	ON STATION
70	2	16	0	32.673	5.7	ON STATION
70	2	17	0	32.672	5.6	ON STATION
70	2	18	0	32.639	5.7	ON STATION

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 70- 1

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DY	GMT	0/00	C	WEST
70	2	19	0	32.674	5.7	ON STATION
70	2	20	0	32.666	5.6	ON STATION
70	2	21	0	32.657	5.6	ON STATION
70	2	22	0	32.655	5.9	ON STATION
70	2	23	0	32.654	6.0	143-30
70	2	24	0		6.8	136-12
70	2	25	0	32.040	9.2	128-42
70	2	25	300	32.240	9.4	127-40
70	2	25	630	31.700	9.5	126-40
70	2	25	915	31.660	9.4	126- 0
70	2	25	1215	31.770	9.3	125-32



SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 70- 2

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DY	GMT	O/OO	C	WEST
70	2	21	500	32.329	9.5	126-40
70	2	21	800	32.333	8.3	127-40
70	2	21	1100	32.202	8.9	128-40
70	2	21	1420	32.474	7.8	129-40
70	2	21	1725	32.522	8.0	130-40
70	2	21	2030	32.453	7.3	131-40
70	2	22	0	32.411	7.2	132-40
70	2	22	300	32.441	7.2	133-40
70	2	22	640	32.466	7.3	134-40
70	2	22	1000	32.522	7.3	135-40
70	2	22	1300	32.479	7.3	136-40
70	2	22	1615	32.453	7.3	137-40
70	2	22	1930	32.494	7.3	138-40
70	2	22	2230	32.547	6.9	139-40
70	2	23	140	32.568	6.5	140-40
70	2	23	500	32.555	6.3	141-40
70	2	23	820	32.611	6.5	142-40
70	2	23	1230	32.651	5.7	143-40
70	2	24	0	32.685	5.4	ON STATION
70	2	25	0	32.675	5.9	ON STATION
70	2	26	0	32.698	5.3	ON STATION
70	2	27	0	32.671	5.4	ON STATION
70	2	28	0	32.677	5.7	ON STATION
70	3	1	0	32.694	5.5	ON STATION
70	3	2	0	32.679	5.3	ON STATION
70	3	3	0	32.680	5.4	ON STATION
70	3	4	0	32.680	5.5	ON STATION
70	3	6	0	32.685	5.4	ON STATION
70	3	7	0	32.670	5.4	ON STATION
70	3	8	0	32.648	5.4	ON STATION
70	3	9	0	32.680	5.3	ON STATION
70	3	10	0	32.652	5.3	ON STATION
70	3	11	0	32.653	5.4	ON STATION
70	3	12	0	32.682	5.2	ON STATION
70	3	13	0	32.669	5.4	ON STATION
70	3	14	0	32.678	5.3	ON STATION
70	3	15	0	32.682	5.3	ON STATION
70	3	16	0	32.701	5.3	ON STATION
70	3	17	0	32.692	5.4	ON STATION
70	3	18	0	32.670	5.4	ON STATION
70	3	19	0	32.679	5.4	ON STATION
70	3	20	0	32.680	5.5	ON STATION
70	3	21	0	32.686	5.3	ON STATION
70	3	22	0	32.672	5.5	ON STATION
70	3	23	0	32.692	5.2	ON STATION
70	3	24	0	32.688	5.3	ON STATION
70	3	25	0	32.682	5.5	ON STATION
70	3	26	0	32.672	5.4	ON STATION
70	3	27	0	32.689	5.5	ON STATION

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 70- 2

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DAY	GMT	0/00	C	WEST
70	3	28	0	32.679	5.5	ON STATION
70	3	29	0	32.672	5.5	ON STATION
70	3	30	0	32.671	5.6	ON STATION
70	3	31	0	32.676	5.7	ON STATION
70	4	1	0	32.704	5.5	ON STATION
70	4	2	0	32.682	5.5	ON STATION
70	4	3	0	32.689	5.7	ON STATION
70	4	4	0	32.683	5.6	ON STATION
70	4	5	0	32.650	5.5	ON STATION

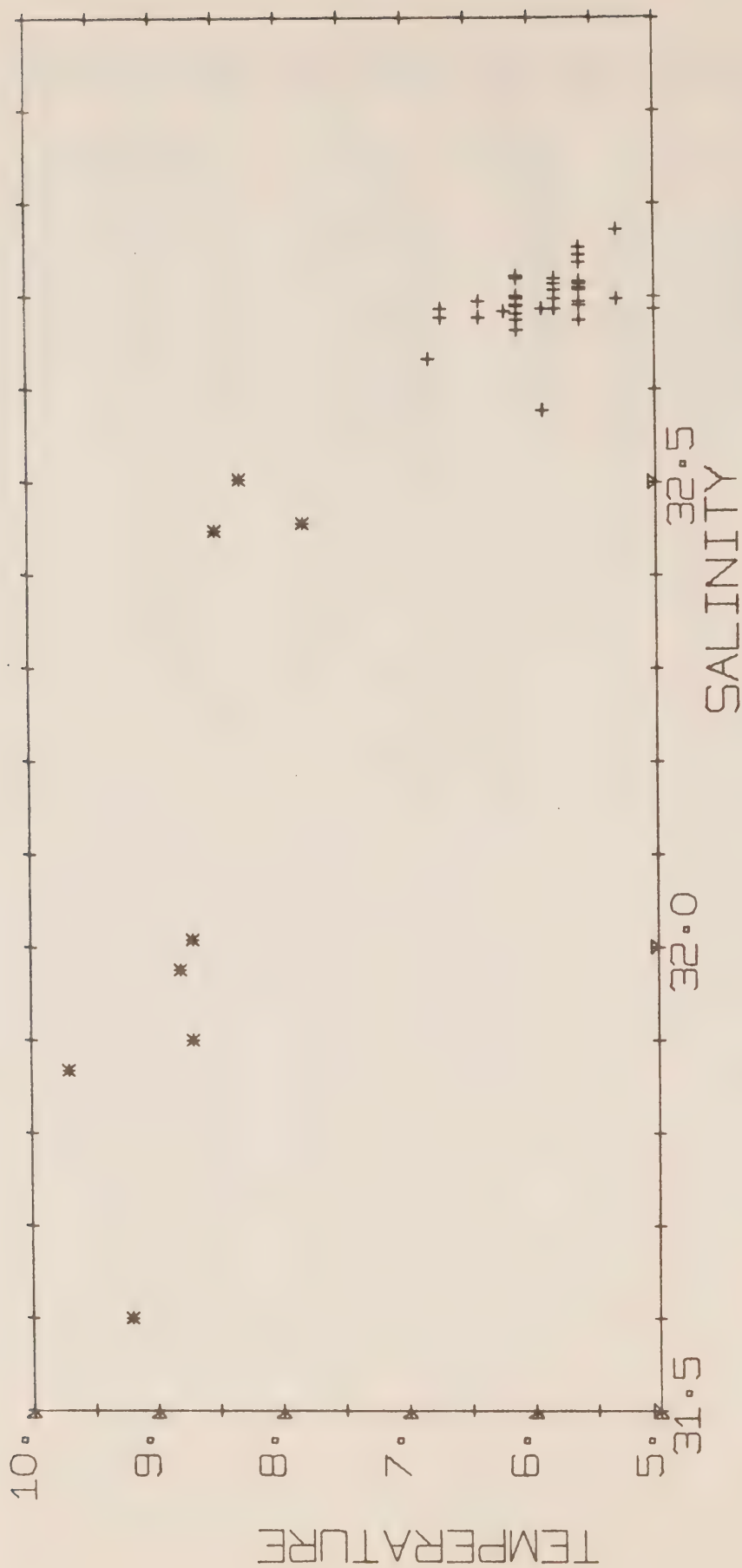


Fig. 8 T-S plot of surface temperature and salinity observations on Line P (asterisks) and at Station P (pluses) during Cruise P-70-3.

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 70- 3

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DAY	GMT	0/00	C	WEST
70	4	4	250	31.868	9.7	125-32
70	4	4	430	31.600	9.2	126- 0
70	4	4	700	31.975	8.8	126-40
70	4	4	1020	31.900	8.7	127-40
70	4	4	1630	32.008	8.7	129-40
70	4	4	1930	32.447	8.5	130-40
70	4	4	2240	32.503	8.3	131-40
70	4	5	230	32.456	7.8	132-40
70	4	6	230	32.632	6.8	138-40
70	4	7	0	32.709	5.6	ON STATION
70	4	8	0	32.753	5.6	ON STATION
70	4	9	0	32.736	5.6	ON STATION
70	4	10	0	32.687	5.0	145-58
70	4	11	0	32.697	5.3	ON STATION
70	4	12	0	32.709	5.6	ON STATION
70	4	13	0	32.709	5.6	ON STATION
70	4	14	0	32.674	5.6	ON STATION
70	4	15	0	32.690	5.6	ON STATION
70	4	16	0	32.713	5.6	ON STATION
70	4	17	0	32.686	5.9	ON STATION
70	4	18	0	32.700	6.1	ON STATION
70	4	19	0	32.690	5.6	ON STATION
70	4	20	0	32.694	5.6	ON STATION
70	4	21	0	32.697	5.8	ON STATION
70	4	22	0	32.719	5.8	ON STATION
70	4	23	0	32.686	5.8	ON STATION
70	4	24	0	32.745	5.6	ON STATION
70	4	25	0	32.771	5.3	ON STATION
70	4	26	0	32.716	5.6	ON STATION
70	4	27	0	32.715	5.6	ON STATION
70	4	28	0	32.724		ON STATION
70	4	29	0	32.707	5.8	ON STATION
70	4	30	0	32.664	6.1	ON STATION
70	5	1	0	32.697	6.1	ON STATION
70	5	2	0	32.691	6.1	ON STATION
70	5	3	0	32.687	6.7	ON STATION
70	5	4	0	32.722	6.1	ON STATION
70	5	5	0	32.707	5.6	ON STATION
70	5	6	0	32.677	6.7	ON STATION
70	5	7	0	32.675	6.1	ON STATION
70	5	8	0	32.681	6.1	ON STATION
70	5	9	0	32.714	5.8	ON STATION
70	5	10	0	32.719	6.1	144-23
70	5	11	0	32.694	6.4	ON STATION
70	5	12	0	32.700	6.1	ON STATION
70	5	13	0	32.577	5.9	144-30
70	5	14	0	32.677	6.4	ON STATION
70	5	15	0	32.677	6.4	ON STATION
70	5	16	0	32.684	6.2	ON STATION

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 70- 3

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DY	GMT	0/00	C	WEST
70	5	17	0	32.689	6.1	ON STATION

©
INFORMATION CANADA
OTTAWA 1973

AI EP 321
- 71R03

Government
Publications

OCEANOGRAPHIC OBSERVATIONS IN THE BEAUFORT SEA JULY 15 - SEPTEMBER 4, 1970

by

Handwritten: D.A. Healey



Handwritten: Canada
DEPARTMENT OF FISHERIES AND FORESTRY
MARINE SCIENCES BRANCH
PACIFIC REGION
Handwritten: 8-1000
512 FEDERAL BLDG
VICTORIA, B.C.
Handwritten: 7-2-71



MARINE SCIENCES BRANCH, PACIFIC REGION

PACIFIC MARINE SCIENCE REPORT NO. 71-3

OCEANOGRAPHIC OBSERVATIONS IN THE BEAUFORT SEA

July 15 - September 4, 1970

by

D. A. Healey

Marine Sciences Branch
Department of Fisheries and Forestry

TABLE OF CONTENTS

	Page
TABLE OF CONTENTS.....	1
LIST OF FIGURES.....	ii
INTRODUCTION.....	1
SUMMARY OF OPERATIONS.....	1
OBSERVATIONAL PROCEDURES.....	2
CURRENT METER OBSERVATIONS.....	3
DRIFT CURRENT OBSERVATIONS.....	4
ACKNOWLEDGEMENTS.....	6
REFERENCES.....	6
TEMPERATURE AND SALINITY OBSERVATIONS.....	25

LIST OF FIGURES

- Figure 1. Stations occupied for salinity-temperature measurements and/or sediment sampling.
- Figure 2. Progressive vector diagram of surface currents at $69^{\circ} 39.5' \text{ N}$, $133^{\circ} 40.0' \text{ W}$, July 16-18, 1970.
- Figure 3. Progressive vector diagram of surface currents at $69^{\circ} 51.7' \text{ N}$, $134^{\circ} 22.7' \text{ W}$, July 24-26, 1970.
- Figure 4. Tracking session, Kugmallit Bay, July 21, 1970.
- Figure 5. Tracking session, Kugmallit Bay, July 22, 1970.
- Figure 6. Tracking session, Kugmallit Bay, July 23, 1970.
- Figure 7. Tracking session, Kugmallit Bay, July 31, 1970.
- Figure 8. Tracking session, Kugmallit Bay, August 21, 1970.
- Figure 9. Tracking session, Kugmallit Bay, August 30, 1970.
- Figure 10. Tracking session, Kugmallit Bay, September 4, 1970.
- Figure 11. Tracking session, Pullen Island, July 27, 1970.
- Figure 12. Tracking session, Hooper Island, July 28, 1970.
- Figure 13. Tracking session, Atkinson Point, August 23, 1970.
- Figure 14. Tracking session, Atkinson Point, August 24, 1970.
- Figure 15. Tracking session, Pullen Island, August 28, 1970.
- Figure 16. Tracking session, Pullen Island, August 31, 1970.
- Figure 17. Tracking session, Pullen Island, September 1, 1970.

INTRODUCTION

CSS RICHARDSON was one of four Canadian survey vessels operating in the Western Canadian Arctic during the summer of 1970. A co-operative program of physical oceanography, seismic profiling and sediment sampling was carried out near-shore in the Beaufort Sea. The sediment samples complement those collected off-shore by CSS PARIZEAU, CSS BAFFIN and CSS HUDSON. The seismic profiles complement those collected offshore by HUDSON.

RICHARDSON was operated by personnel of the Canadian Hydrographic Service, Marine Sciences Branch, Department of Energy, Mines and Resources, Victoria, B. C. Participating scientific personnel were from the Pacific Oceanographic Group, Nanaimo, B. C. and from the Atlantic Oceanographic Laboratory, Dartmouth, N.S. Data from the physical oceanographic program are presented in this report.

SUMMARY OF OPERATIONS

Ship's personnel proceeded to Tuktoyaktuk during the last week in May to prepare RICHARDSON for field operations. Scientific personnel joined RICHARDSON on July 9. A delay in the delivery of lifesaving equipment postponed the start of operations until July 15. During the period July 15 to August 1, profiles of temperature and salinity, current measurements and sediment samples were obtained in the Kugmallit Bay area. Operations were hampered somewhat by ice conditions. Offshore winds during the last week of July transported the ice offshore and no ice was encountered for the remainder of the season.

Seismic profiling equipment was loaded and tested in Tuktoyaktuk Harbour August 2 and 3. RICHARDSON proceeded to Herschel Island August 4 and ran seismic lines in the Mackenzie Bay area August 5-14. Two days were spent doing profiling for the Marine Terminal Study, Herschel Island, for the Department of Public Works. RICHARDSON returned to Tuktoyaktuk August 15, exchanged the seismic equipment for side-scan sonar equipment and operated the sonar in the Pullen Island area August 17 - 20.

The sediment sampling program and current observations were resumed August 21, and continued until September 4. Deteriorating weather conditions forced a termination of operations at that time, and winterization of RICHARDSON was started September 5. Ship's personnel and remaining scientific personnel departed Tuktoyaktuk September 8.

OBSERVATIONAL PROCEDURES

Temperature and salinity were observed in-situ with an Industrial Instruments portable salinometer. Salinity accuracy is believed to be ± 0.1 pt. Depths were determined by cable length out.

Two 50 hr. series of surface currents were obtained using a Hydro-Products Model 450S current meter. The current meter was suspended from RICHARDSON, which was at anchor. Current speed was recorded on deck with a Rustrak strip chart recorder. Current direction was determined relative to ships head, which was determined by gyro compass.

Drift current measurements were made by tracking and positioning two types of free floating current followers. Currents at 2 m were measured using parabolic floats and "window blind" drogues, described by Terhune (1968). These followers consisted of a 14 inch diameter parabolic float, complete with pole and flag for identification, and a drogue of 8 ft wide, 6 ft. high and 4 mil polyethylene, lashed to a cedar 1" x 2" on the upper edge and a 5/8" diameter iron bar on the lower edge. The drogue was attached to the float by a bridle with arms at 45° to the horizontal.

Currents in the upper 6 inches were measured by tracking Pains Wessex "Hydrographic Signals". The hydrographic signals consisted of a tire shaped float surrounding twelve smoke flares and a timing mechanism for firing flares. The main part of the float was approximately 6 inches deep and floated with 5 1/2 inches submerged. When deployed, the signals were located by visual sighting of the smoke flares, which were programmed to fire each quarter, half or full hour.

Each tracking session consisted of releasing two or three current followers at the same position, and plotting their positions once per hour. Positions were determined using the Polar Continental Shelf Project Decca positioning system. In the areas worked, positions are accurate to within ± 0.1 miles. Along the baseline extension of the Decca chain, positions were obtained by radar fixes. No tracking session exceeded nine hours, owing to the limited hours of ships operation. Wind information was obtained with hand held anemometer once per hour. Tidal characteristics provided with each tracking session are tides predicted for Tuktoyaktuk.

Sediment samples were obtained with a Van Veen grab. Information on samples obtained is available from Dr. B. Pelletier, Atlantic Oceanographic Laboratory, Bedford Institute, Dartmouth, N.S. Information on the seismic profile records and side-scan sonar records is available from Mr. J. Shearer, Geological Survey of Canada, 601 Booth Street, Ottawa.

CURRENT METER OBSERVATIONS

Current directions were determined relative to the ship's head, as the direction sensor of the Model 450S current meter was inoperable owing to the proximity of the magnetic pole. A drogue was trailed from the ship to determine the current direction relative to the ship, as the ship's head was not always directed into the current. Current directions are thought to be accurate to $\pm 15^\circ$.

During the period July 16-18, a 50 hour series of surface current measurements was obtained. RICHARDSON was anchored in 6 m of water on the western side of Kugmallit Bay, at $69^\circ 39.5' \text{N}$, $133^\circ 40.0' \text{W}$, in the hope of measuring fresh water run-off from the East Channel of the Mackenzie River, which flows into the south-west corner of Kugmallit Bay. A layer of fresh water was overlying a layer of more saline water. The surface salinity was less than 1 ppt, and increased from 6 ppt to 29 ppt between 2 and 3 m. The current meter was suspended at a depth of 1 m.

Results are presented in the form of a progressive vector diagram (figure 2). Each vector represents an average hourly velocity, and time is indicated every four hours. Wind speed and direction are indicated by arrows (20 knots/inch). Winds varied from 0 to 15 knots with a mean speed of 8 knots and mean direction of 087° . Maximum current speed observed was 46 cm per sec. The numbers on the axes represent distance in nautical miles. The current direction was predominately WNW for the entire period.

A second 50 hour series was obtained 4.5 miles north of Pullen Island at $69^\circ 51.7' \text{N}$, $134^\circ 22.7' \text{W}$, during the period July 24-26. RICHARDSON was anchored in 9 m of water, and the current meter was suspended at 1 m, above a marked density increase which was situated between 3 and 5 m. Results are presented in figure 3, a progressive vector diagram identical in format to figure 2. Currents were variable with a general trend southward.

DRIFT CURRENT OBSERVATIONS

- July 21 3 parabolic floats were released together one hour prior to low water; one was retrieved two hours later and the others retrieved two hours after high water. Flow was to the north during the ebb tide and to the west during the flood tide.
- July 22 3 parabolic floats were released two miles NNW of the previous days starting position. Flow during the ebb was northward at approximately 0.5 knots. During the first three hours of the flood, flow was southward at less than 0.3 knots.
- July 23 Two hydrographic signals (red and yellow floats) and one parabolic float (float 14) were released together. The parabolic float with drogue at 2 m. set to the northeast at 0.8 knots and was in danger of being lost from visual contact with the other two floats. Float 14 was retrieved at 1130 and re-deployed at 1201 in the vicinity of the other floats, where it resumed its drift to the northeast. The red and yellow hydrographic signals drifted more slowly to the northeast. Their drift may have been retarded by winds from the NNW.
- July 31 One hydrographic signal and two parabolic floats were launched at 0855. The hydro-signal drifted toward Tuktoyaktuk Harbour with the flood tide and moved into shallow water at 1300. It was retrieved and re-launched at 1320, and drifted southward until the beginning of the ebb, at which time it changed directions to the northeast.
- The parabolic floats remained close to their original positions until the ebb, when they started to move northward.
- August 21 Two parabolic floats and one hydro-signal were launched at 0840. The hydro-signal drifted to the NNE with a following wind at a mean speed of 1.1 knots and did not change directions at the change of tide. The parabolic floats drifted together to the north until the change to flood tide and then drifted to the east. One parabolic float was lost at 1254.
- August 30 One hydro-signal and one parabolic float were released. The hydro-signal drifted to the SSW with the flood tide. The parabolic float with drogue at 2 m. drifted to the SSW for 3 hours, then began to move to the NW although the tide continued to flood.
- Sept. 4 Two parabolic floats and one hydro-signal were released. The parabolic floats drifted to the west until the tide began to flood, at which time they moved off to the SSW. The hydro-signal drifted directly downwind at 0.5 knots until it became

trapped in a convergence line which was obvious due to the debris gathered at the interface between muddy river water and clean water to the north. It remained in the convergence zone until retrieved three hours later.

July 27 Three parabolic floats were released together and drifted directly downwind until retrieved.

July 28 Three parabolic floats were released and again drifted downwind until retrieved.

August 23 One hydro-signal and one parabolic float were launched and proceeded downwind to the ESE. The hydro-signal drifted 10.5 miles in 5.8 hours and the parabolic float drifted 8.8 miles in 6.8 hours.

August 24 One hydro-signal and one parabolic float were released under similar circumstances as the previous day, except that the winds had shifted considerably. Their original drift was in the same direction as that of the previous day, but at a decreased speed. When the wind became calm between 1230 and 1330, the current followers both changed directions, the parabolic float turning to the north and the hydro-signal turning to the south.

August 28 One parabolic float and one hydro-signal were released. Both drifted to the east. When the wind increased to over 20 knots at 1500, the hydro-signal moved off at a greatly increased speed.

August 31 Current followers were tracked for four hours.

Sept. 1 Two current followers were released north of Pullen Island. The hydro-signal drifted immediately downwind whereas the parabolic float moved southward for four hours before turning to westward.

ACKNOWLEDGEMENTS

The assistance received from Captain Dale-Johnson and the crew of RICHARDSON was appreciated.

The progressive vector diagrams were produced by Mr. Delbert Smith. The figures were prepared by Mrs. V. Nadon.

REFERENCES

- Canadian Hydrographic Service. 1970. Canadian Tide and Current Tables. Volume 4, Arctic and Hudson Bay. Marine Sciences Branch, Department of Energy, Mines and Resources, Ottawa.
- Terhune, L.D.B. 1968. Free Floating Current Followers. Fisheries Research Board of Canada, Technical Report No. 85. 34 p.

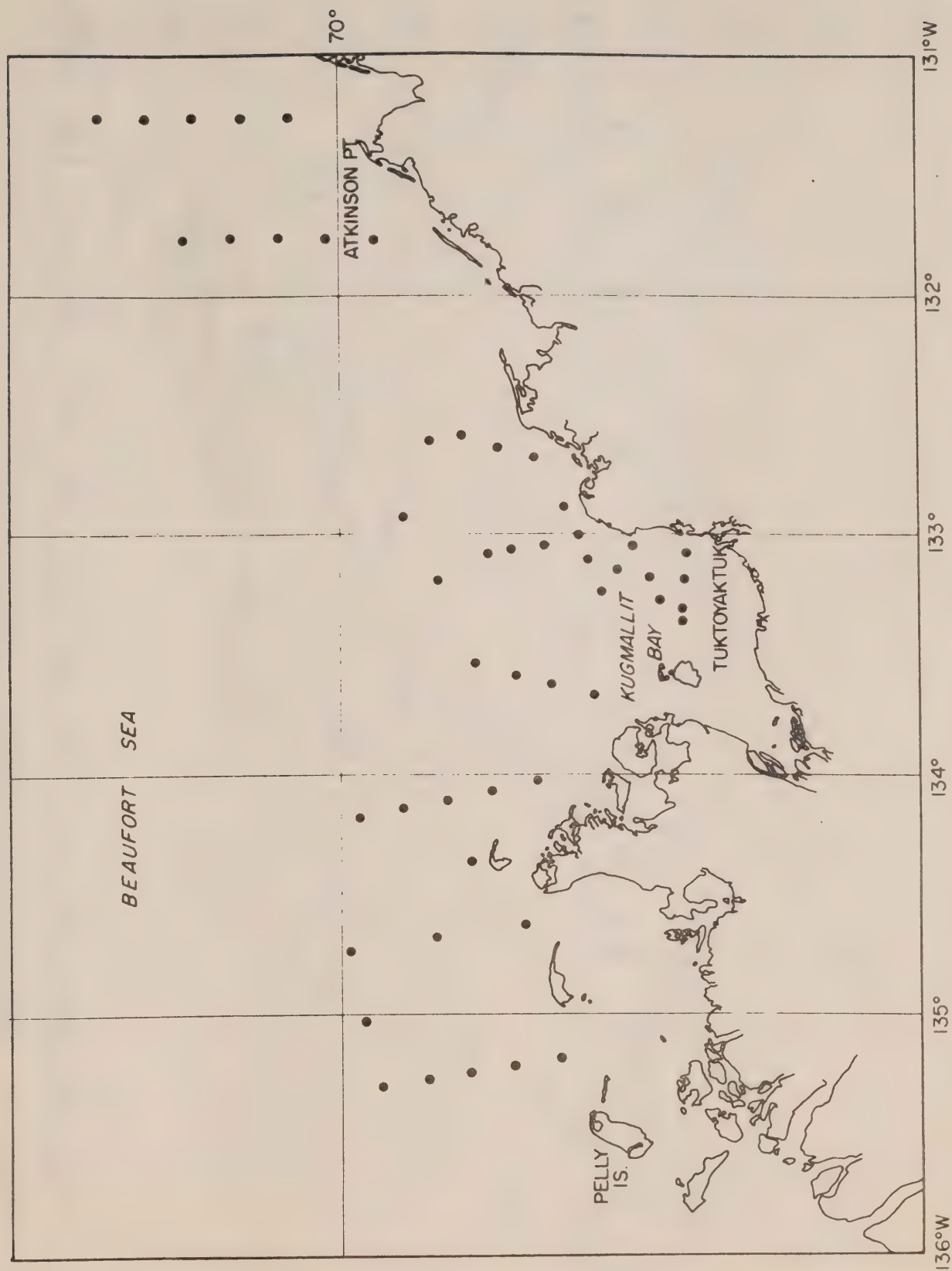


Figure 1. Stations occupied for salinity-temperature measurements and/or sediment sampling.

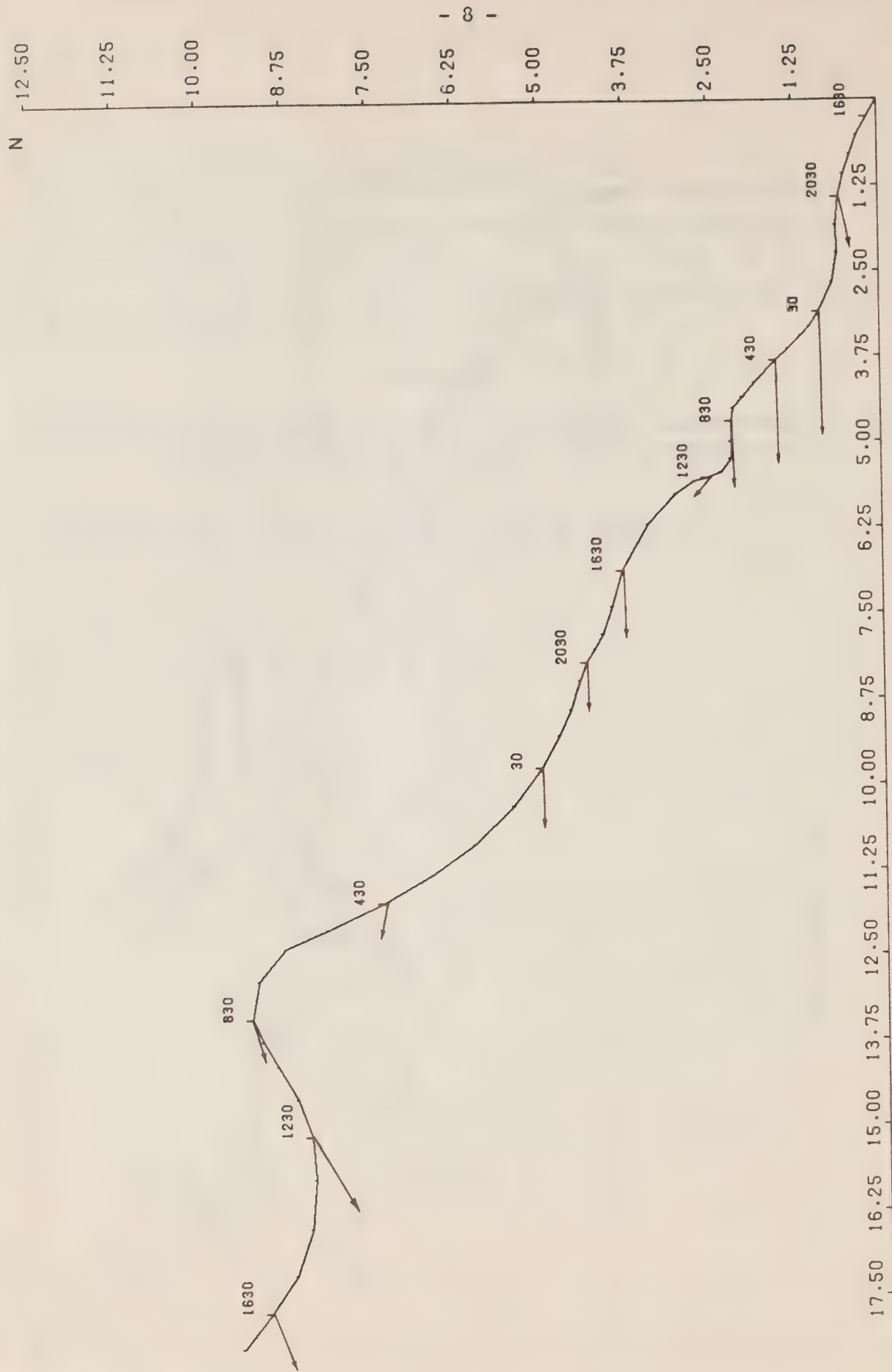


Figure 2. Progressive vector diagram of surface currents at 69° 39.5' N, 133° 40.0' W, July 16-18, 1970.

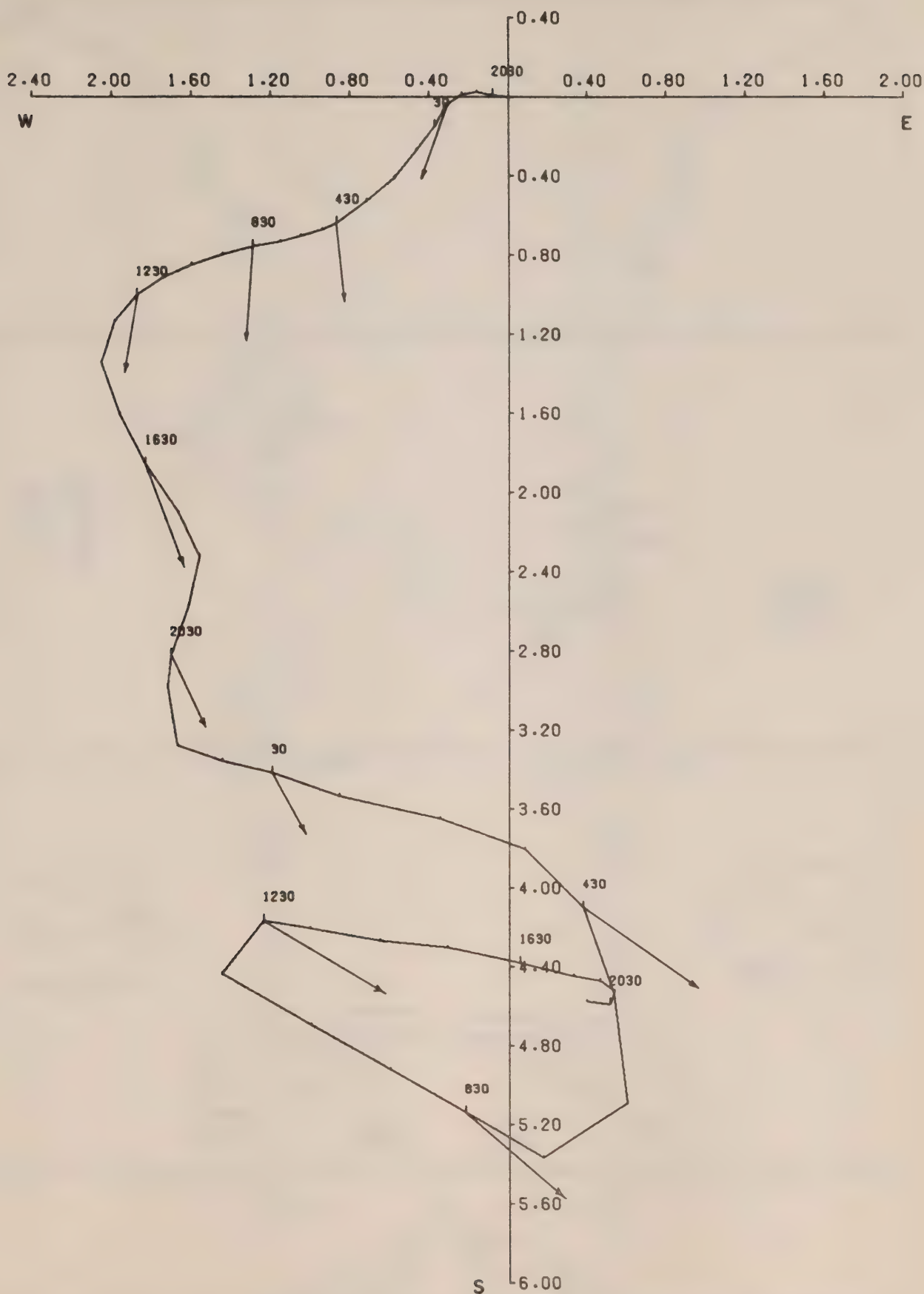


Figure 3. Progressive vector diagram of surface currents at 69° 51.1' N, 134° 22.7' W, July 24-26.

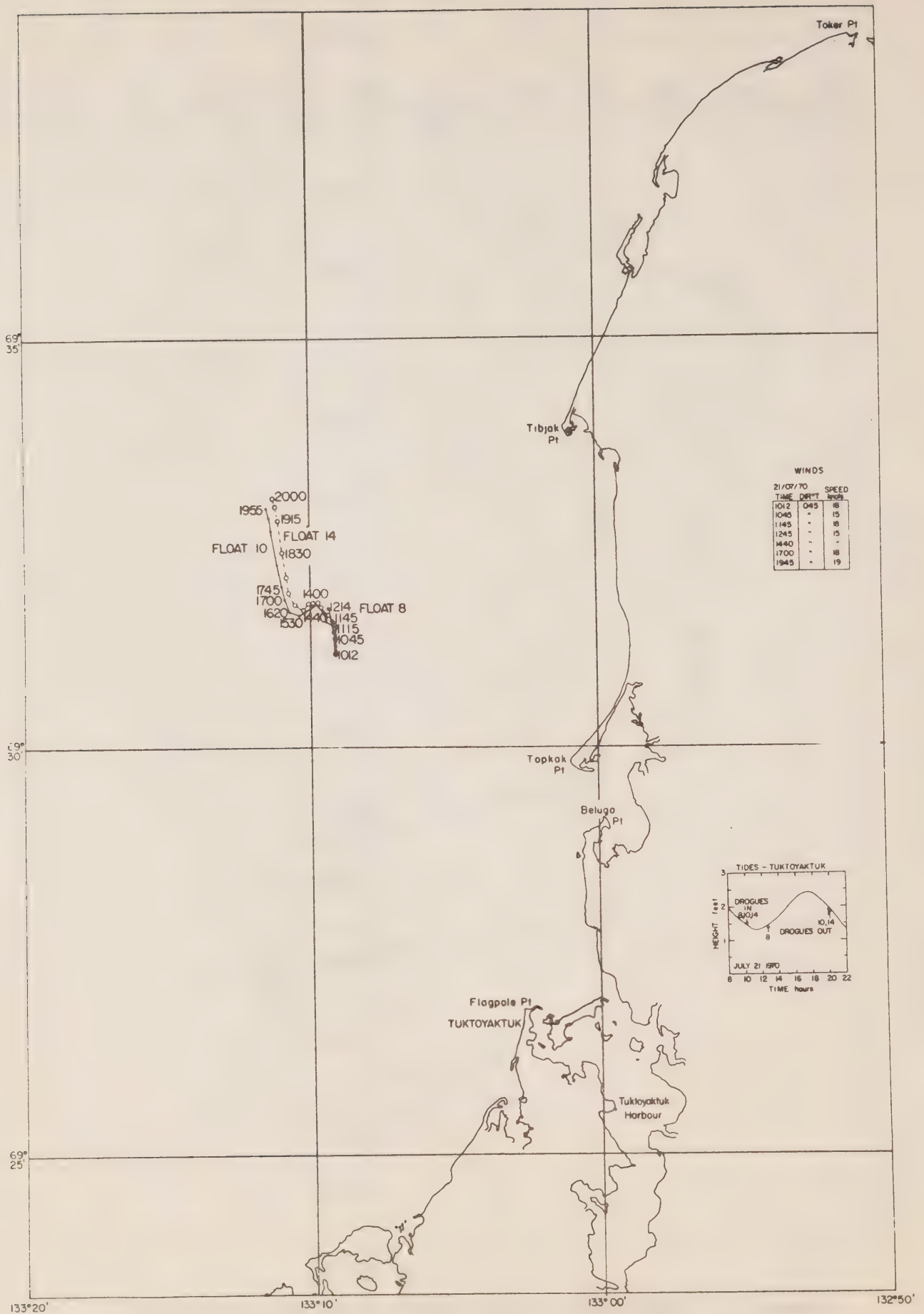


Figure 4. Tracking session, Kugmallit Bay, July 21, 1970.

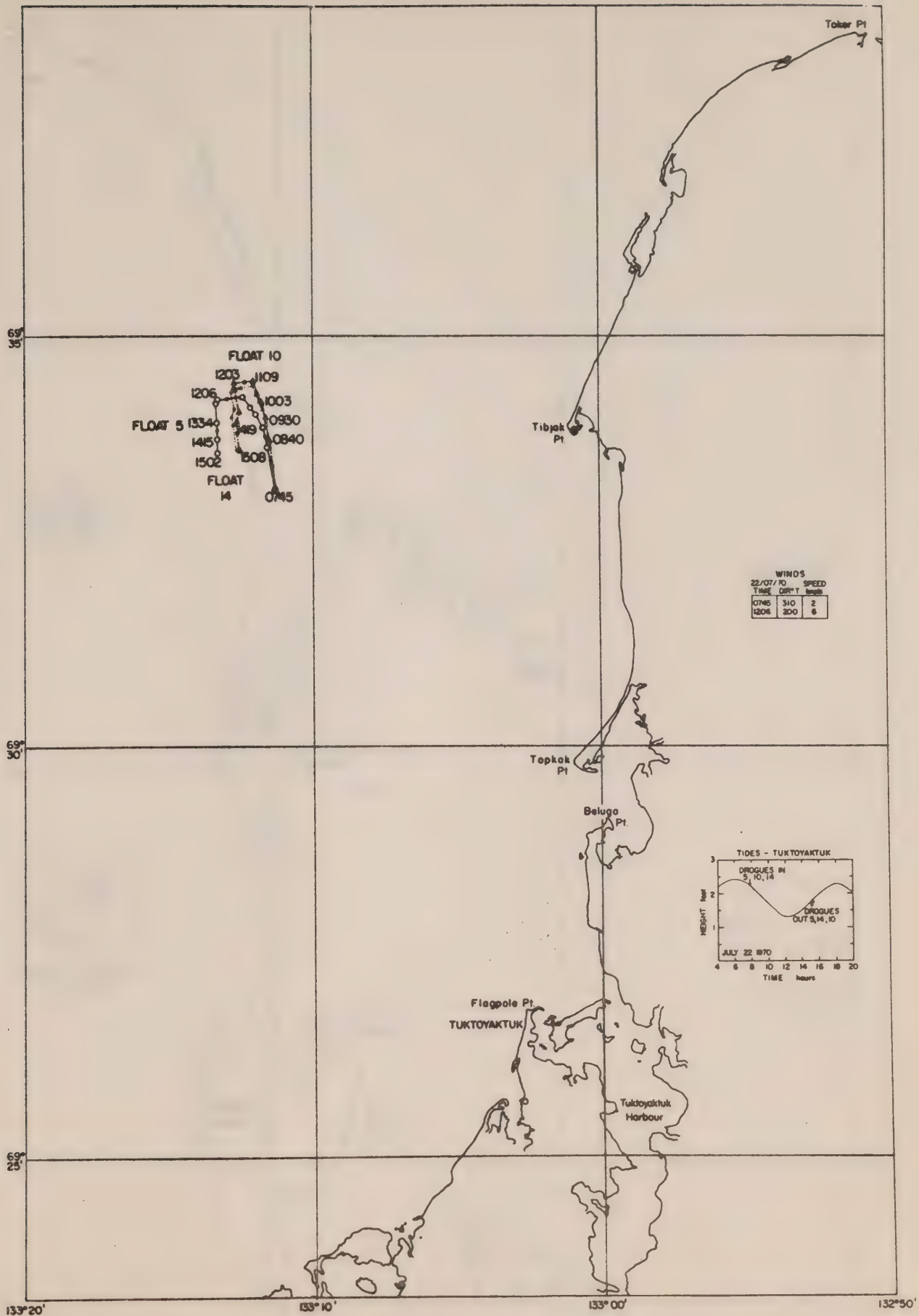


Figure 5. Tracking session, Kugmallit Bay, July 22, 1970.

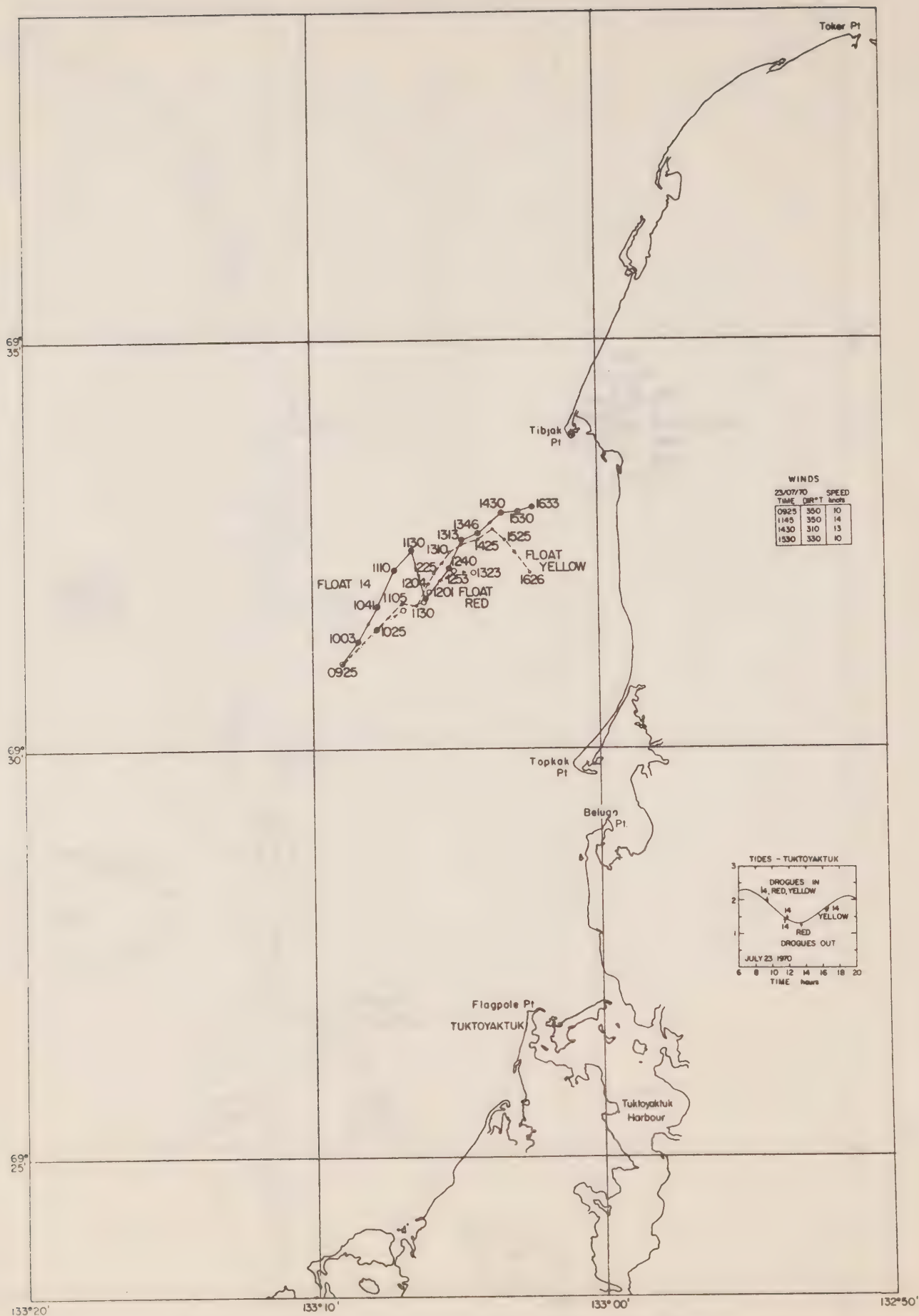


Figure 6. Tracking session, Kugmallit Bay, July 23, 1970.

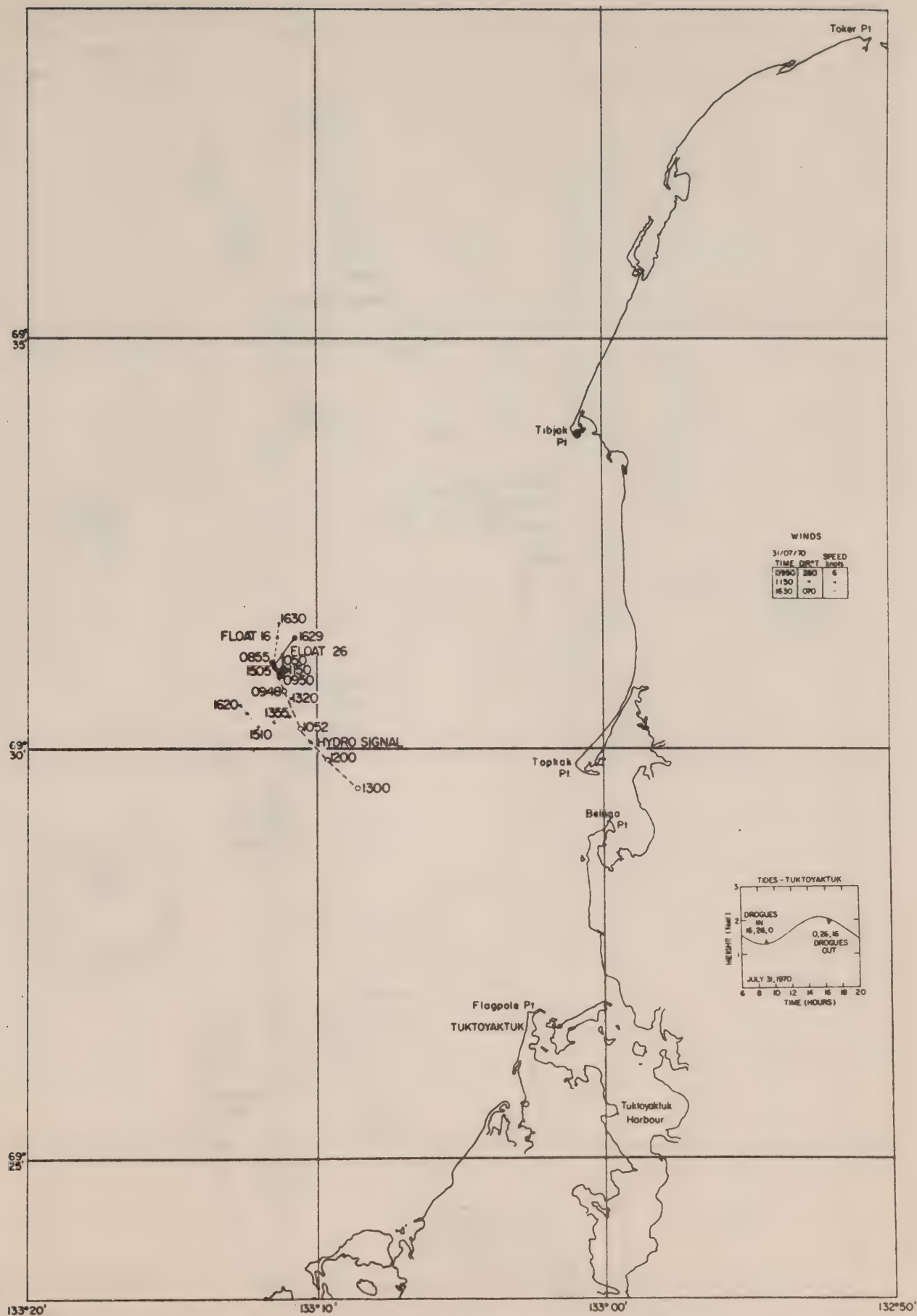


Figure 7. Tracking session, Kugmallit Bay, July 31, 1970.

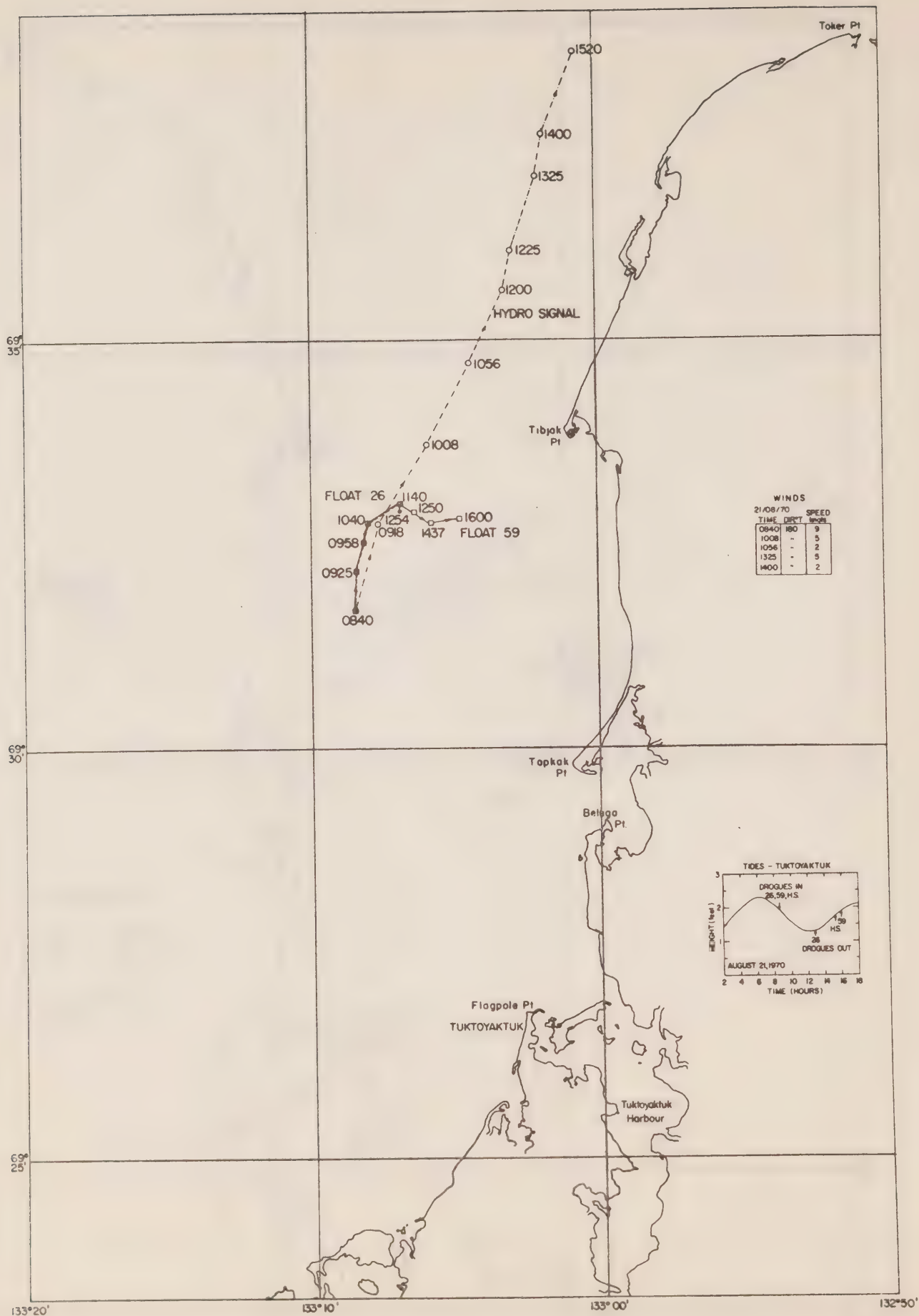


Figure 8. Tracking session, Kugmallit Bay, August 21, 1970.

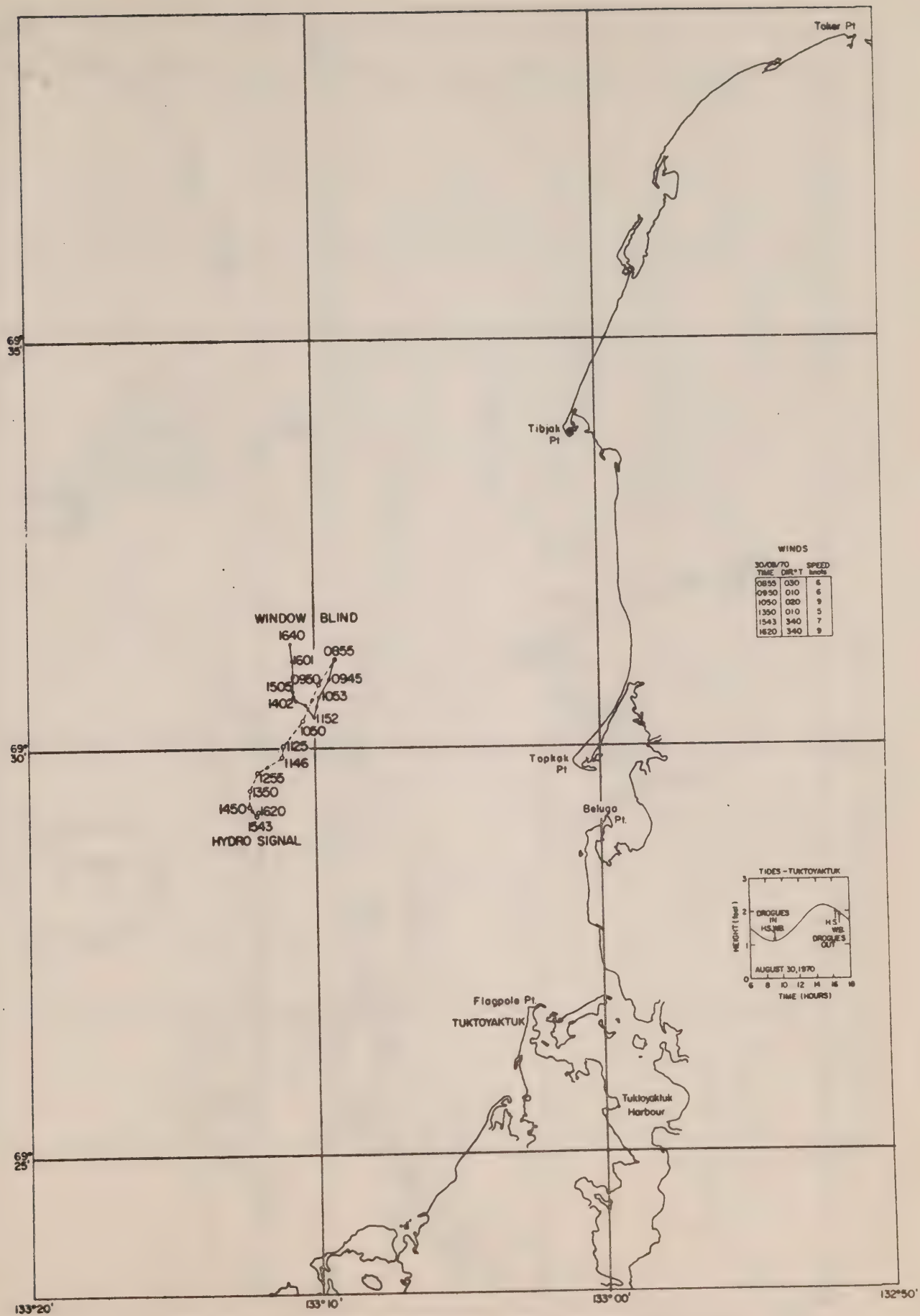


Figure 9. Tracking session, Kugmallit Bay, August 30, 1970.

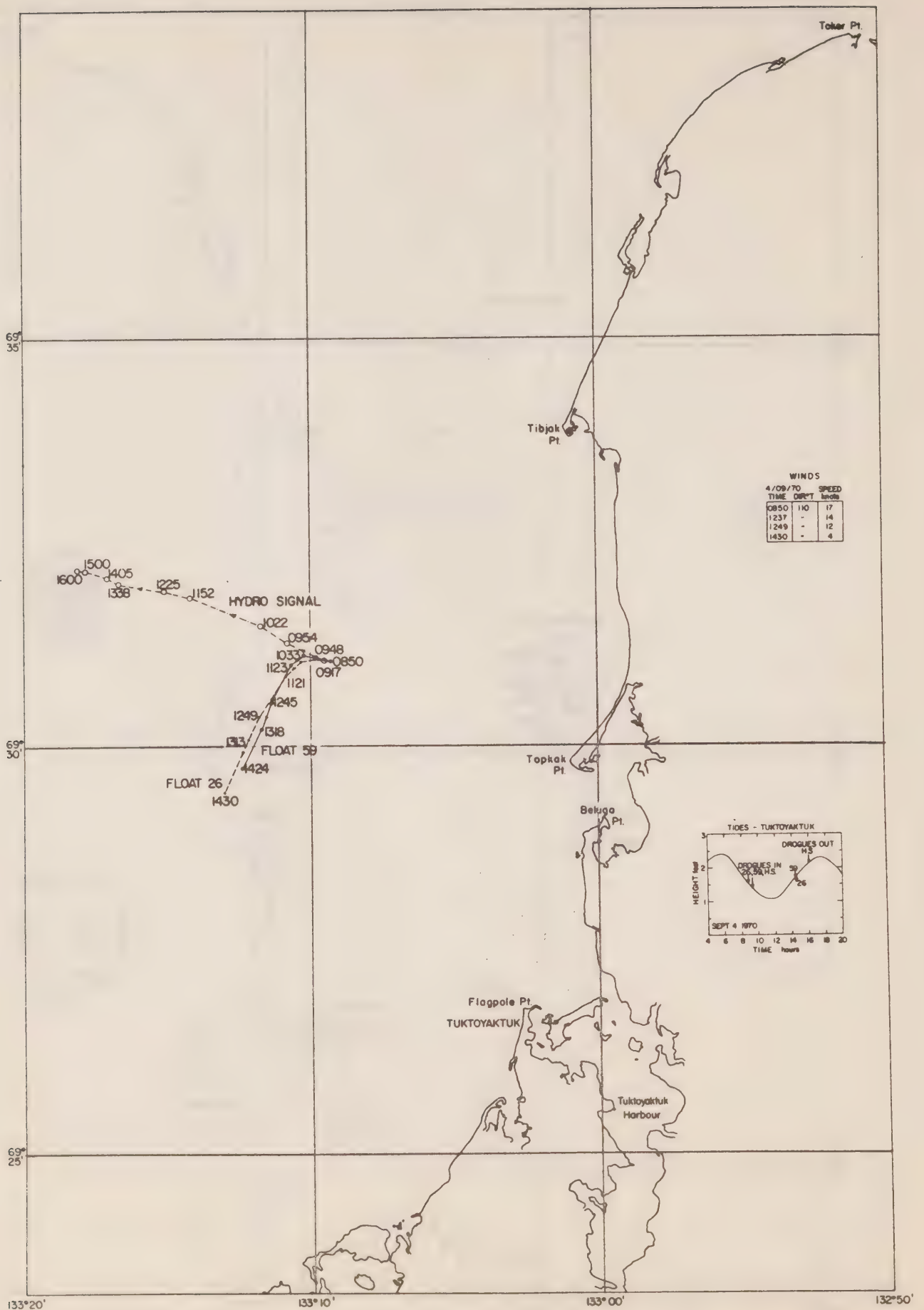


Figure 10. Tracking Session, Kugmallit Bay, Sept. 4, 1970.

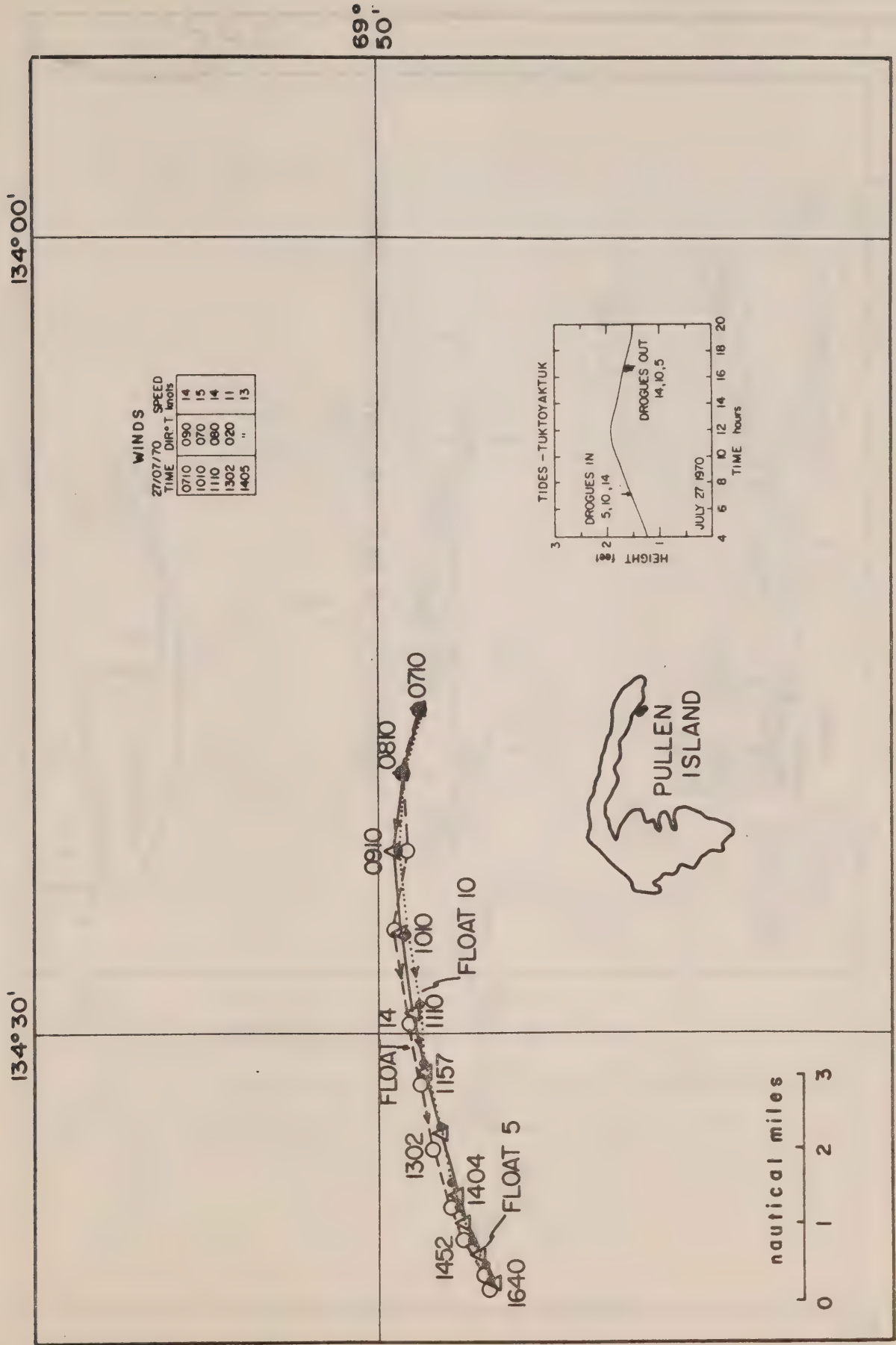


Figure 11. Tracking session, Pullen Island, July 27, 1970.

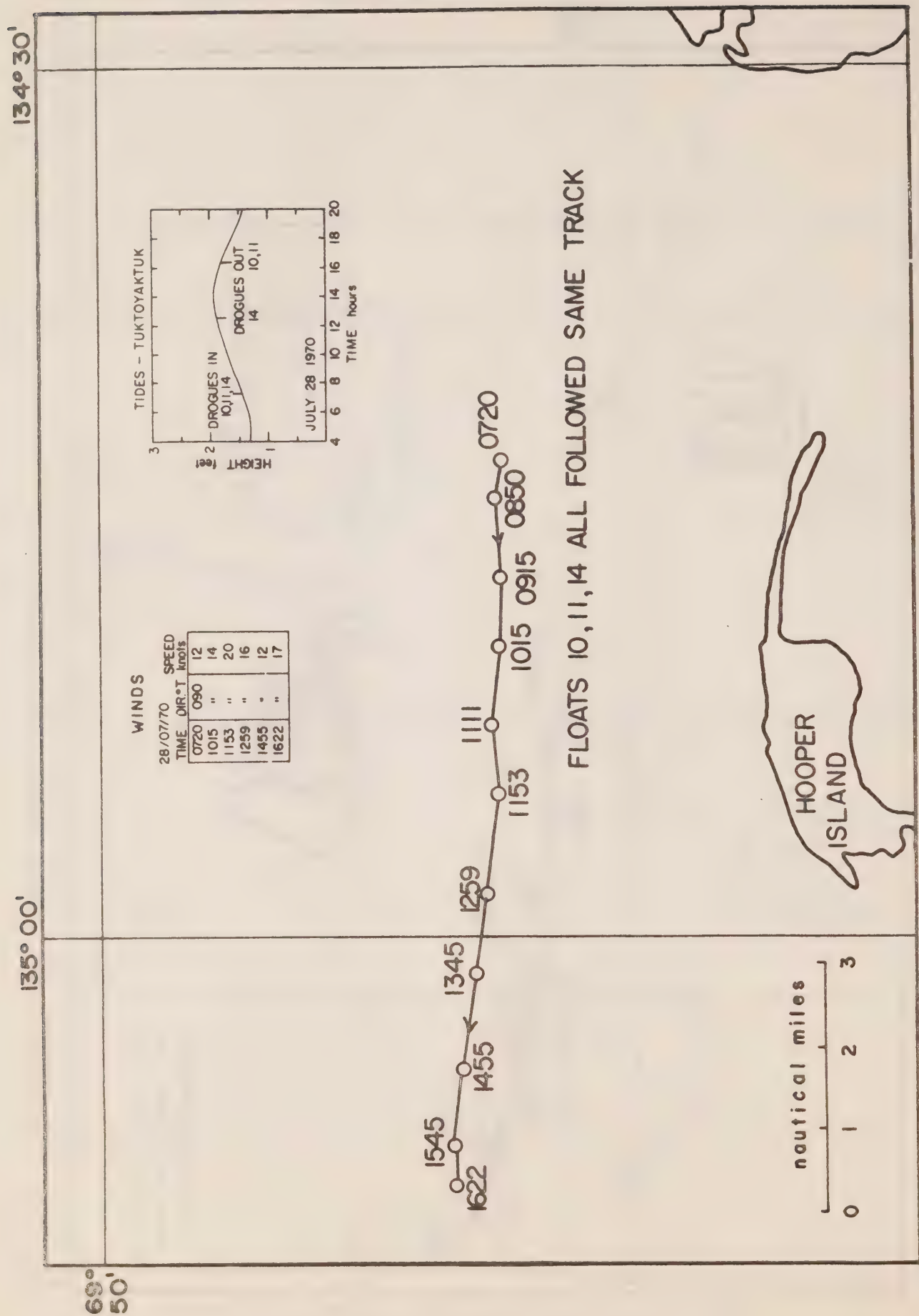


Figure 12. Tracking session, Hooper Island, July 28, 1970.

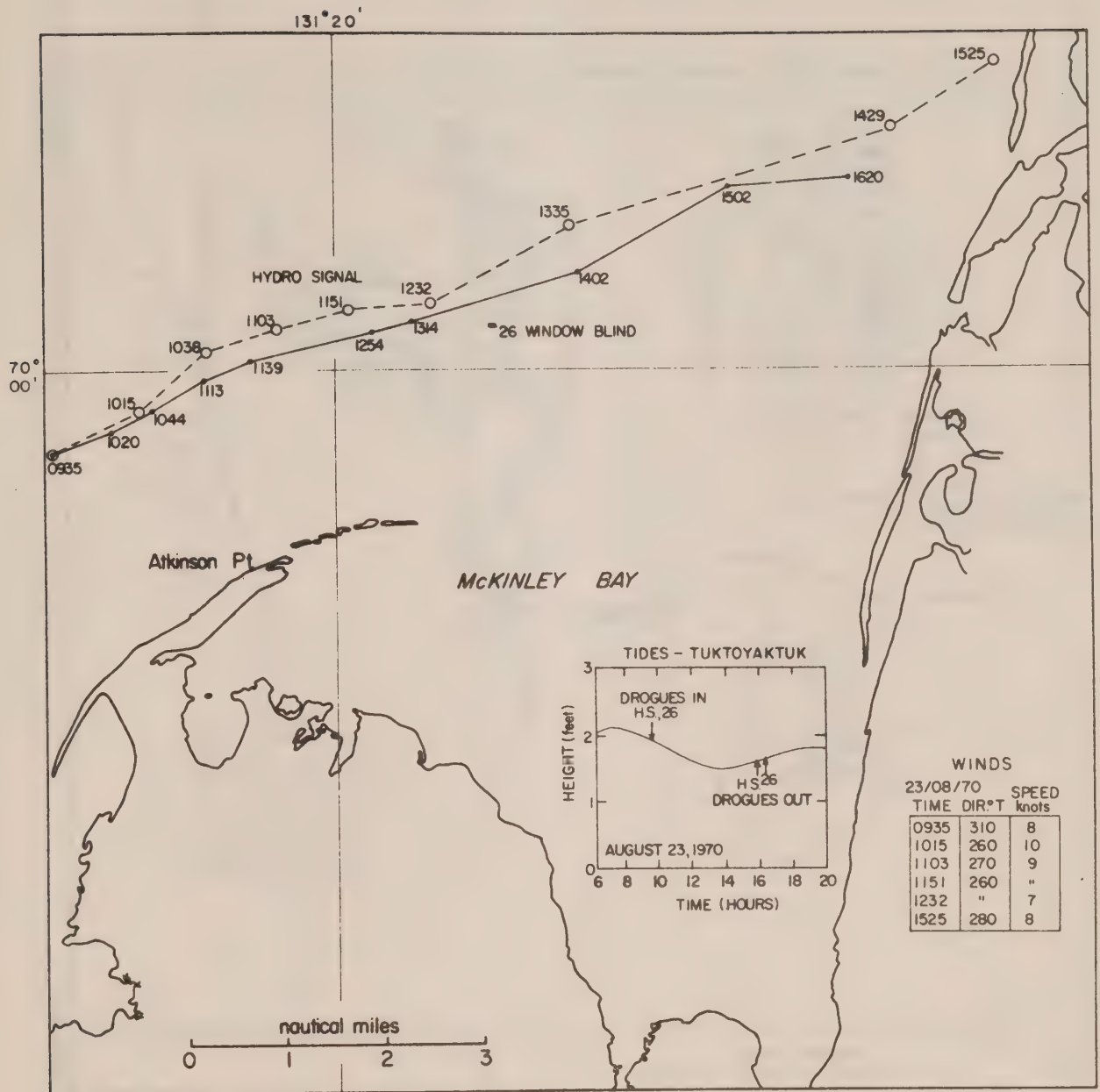


Figure 13. Tracking session, Atkinson Point, August 23, 1970.

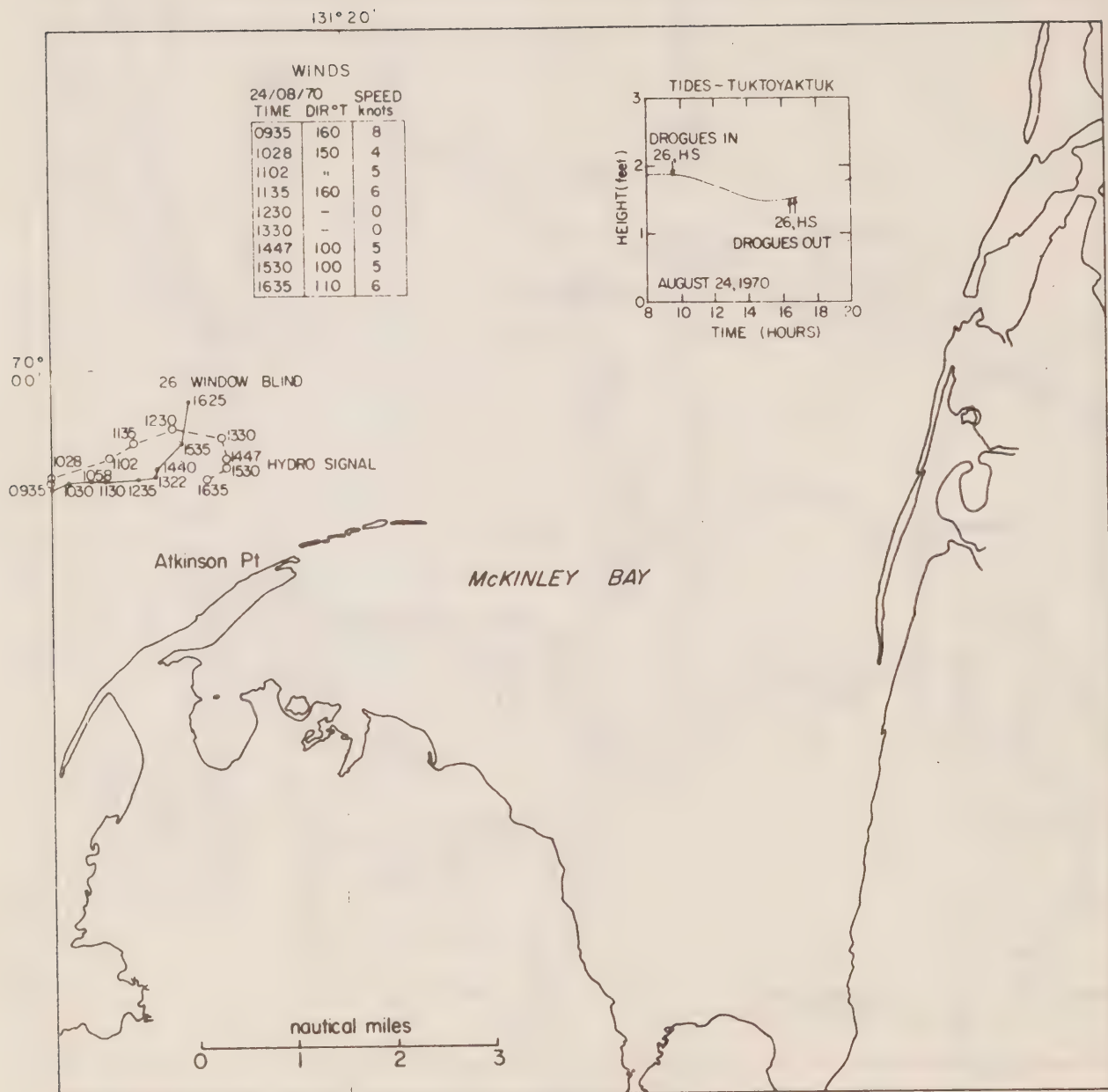


Figure 14. Tracking session, Atkinson Point, August 24, 1970.

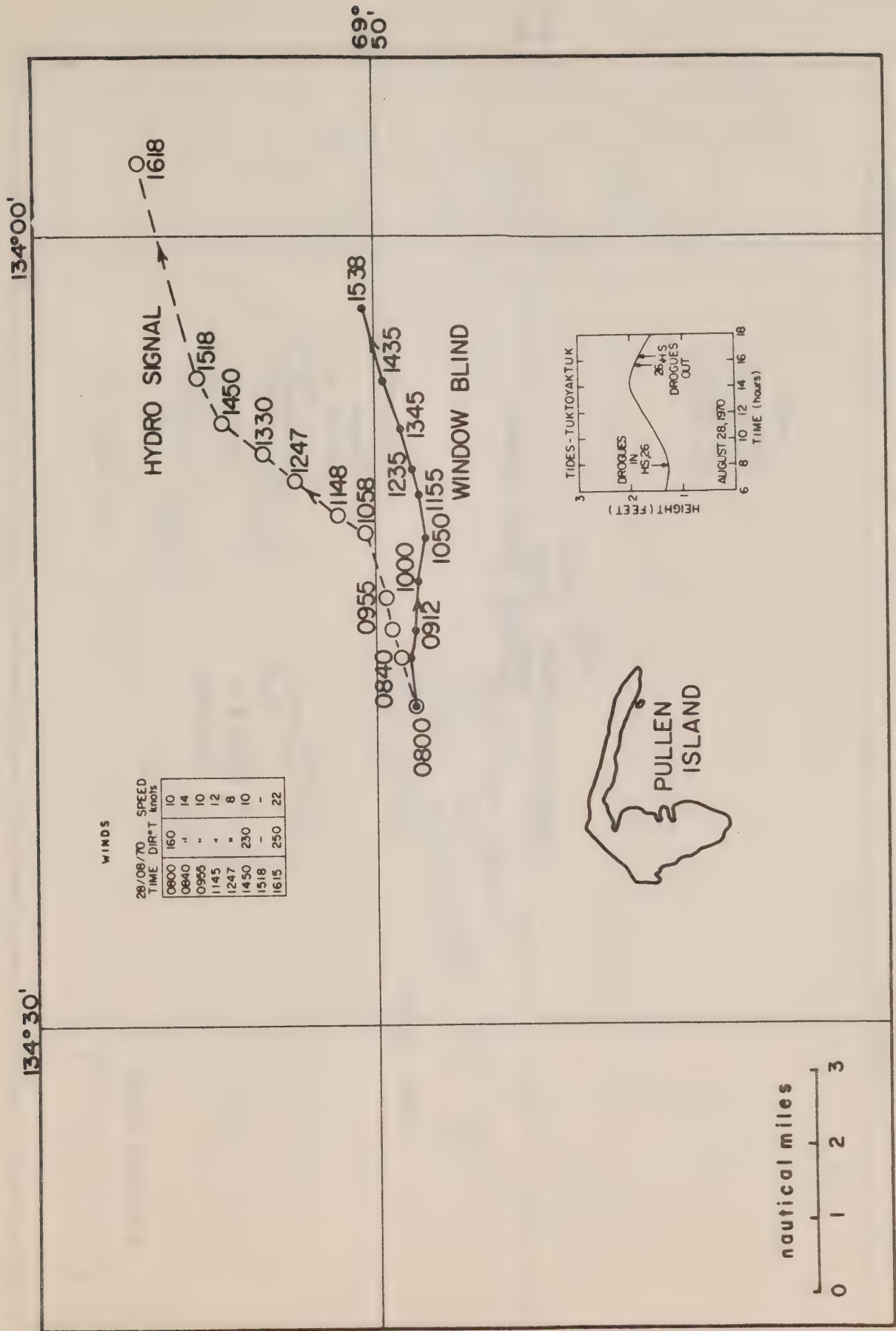


Figure 15. Tracking session, Pullen Island, August 28, 1970.

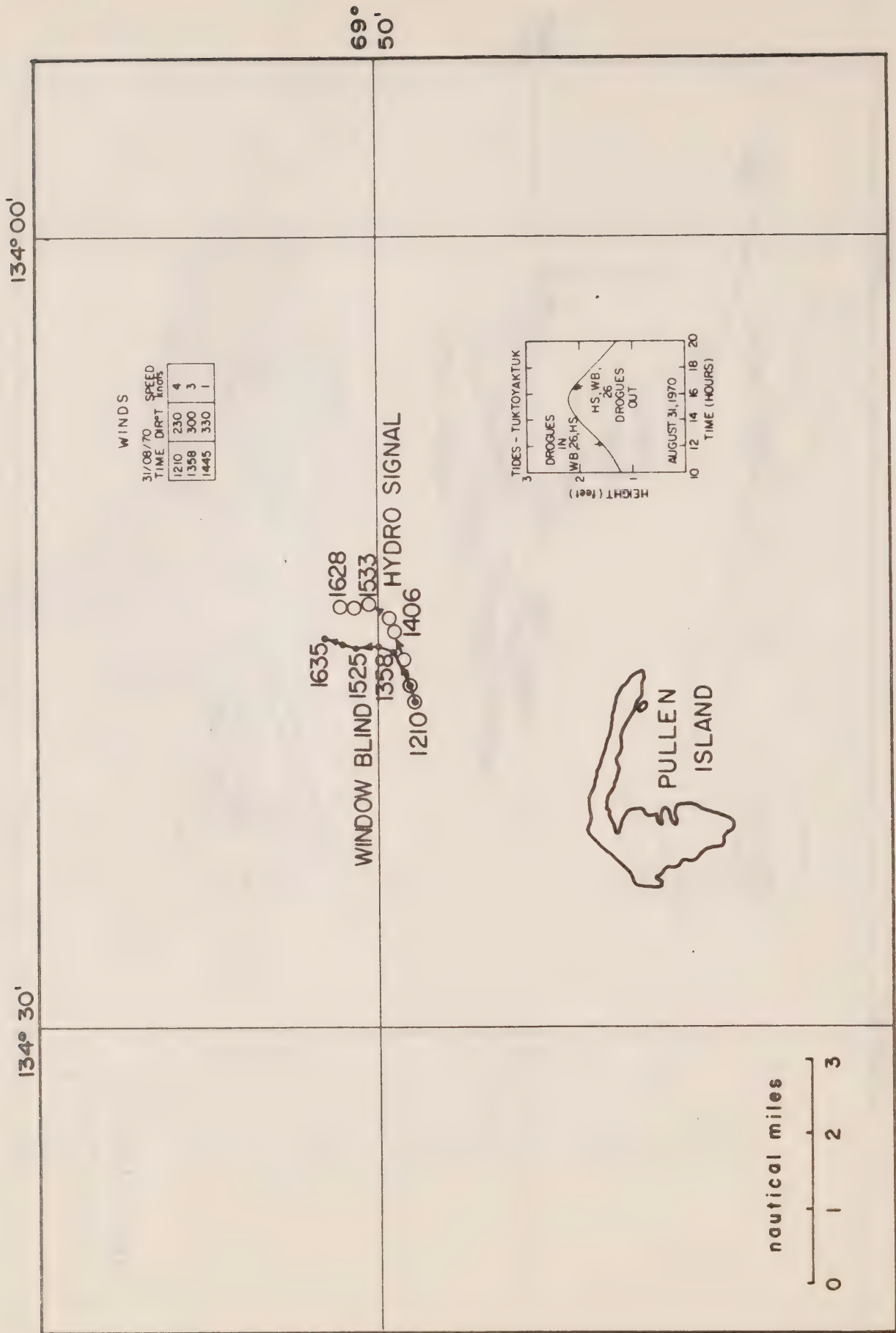


Figure 16. Tracking session, Pullen Island, August 31, 1970.

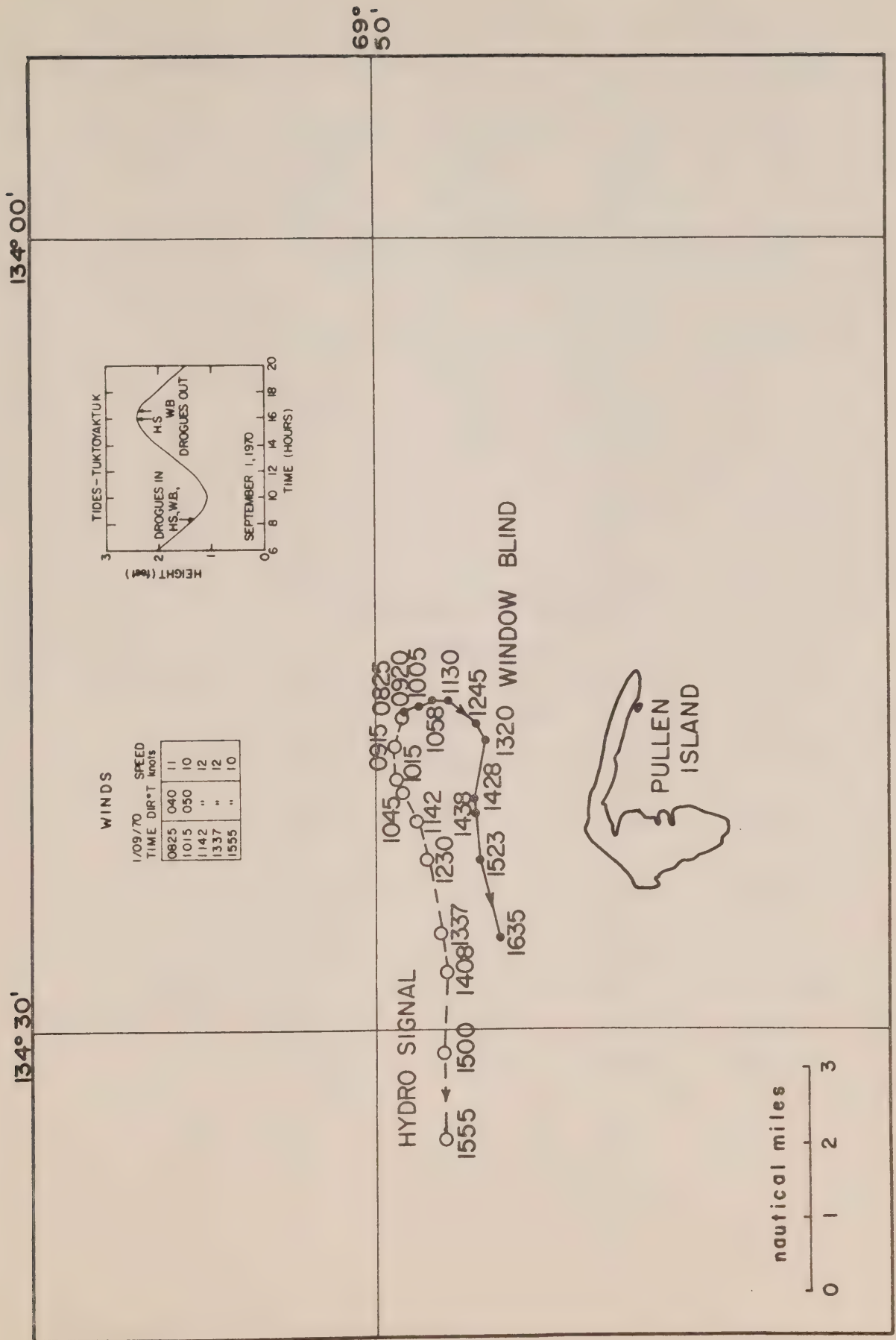


Figure 17. Tracking session, Pullen Island, Sept. 1, 1970.

TEMPERATURE AND SALINITY

OBSERVATIONS

Temp. °C

Salinity ppt

Depth m

Station No. 2 69 30.5 N 133 05.3 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	11.70	0.54	0.01
4	9.81	0.58	0.22

Station No. 3 69 30.6 N 133 10.9 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	8.29	0.66	0.40
4	4.31	0.64	0.54

Station No. 4 69 30.8 N 133 16.2 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	13.50	0.39	-0.33
3	12.04	0.39	-0.15

Station No. 5 69 32.2 N 133 16.5 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	9.72	0.46	0.14
3	8.04	0.52	0.31

Station No. 6 69 33.5 N 133 11.1 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	3.10	0.83	0.69
4	0.68	22.19	17.82

Station No. 7 69 34.6 N 133 02.9 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	7.26	0.80	0.57
3	7.20	0.84	0.61

Station No. 8 69 36.0 N 133 08.5 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	3.75	0.90	0.75
4	-0.09	25.83	20.74

Station No. 9 69 37.5 N 133 14.6 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	5.97	0.94	0.74
4	-0.20	28.18	22.66

Station No. 10 69 38.6 N 133 07.1 W 15/07/70

Depth	Temp.	Salinity	Sigma t
0	4.18	1.10	0.91
5	-0.68	28.17	22.65

Station A 69 39.5 N 133 40.0 W 17/07/70

Depth	Temp.	Salinity	Sigma t
0	10.80	0.94	0.41
2	6.48	6.42	5.06
3	0.24	29.36	23.56
4	-0.88	30.02	24.13

Station No. 11 69 44.2 N 133 03.2 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	9.22	12.47	9.58
2	3.48	23.46	18.70
3	-0.38	29.16	23.41
5	-0.53	30.10	24.19
6	-1.06	30.45	24.50

Station No. 12 69 42.2 N 132 55.4 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	8.38	16.69	12.95
2	2.24	27.87	22.29
4	-0.80	31.21	25.09
5	-0.60	31.17	25.06

Station No. 13 69 42.2 N 133 03.6 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	6.72	12.80	10.06
2	7.30	16.10	12.60
4	-0.51	28.51	22.93
6	-1.07	31.31	25.19

Station No. 14 69 45.0 N 133 03.6 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	7.67	4.43	3.42
2	7.55	10.80	8.43
4	0.92	26.62	21.35
6	-0.72	30.17	24.25

Station No. 15 69 47.7 N 133 05.2 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	7.69	5.40	4.18
2	7.84	6.41	4.96
4	0.39	27.37	21.98
6	-0.18	30.95	24.87
8	-0.81	31.03	24.96
9	-1.22	31.50	25.35

Station No. 16 69 51.5 N 133 10.1 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	6.52	2.90	2.28
2	6.31	3.17	2.50
4	-0.57	28.20	22.67
6	-0.64	29.91	24.05
8	-1.11	30.98	24.91
10	-1.14	31.80	25.58
12	-1.14	32.02	25.76
14	-1.34	32.52	26.18

Station No. 17 69 52.7 N 132 54.7 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	5.44	3.60	2.88
2	5.12	4.58	3.66
4	-0.01	27.68	22.24
6	-0.70	30.02	24.12
8	-0.74	30.56	24.56
10	-0.93	31.34	25.20
12	-1.30	32.18	25.89

Station No. 19 69 51.7 N 132 35.9 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	6.30	3.57	2.82
2	0.49	25.94	20.83
4	-1.01	28.89	23.23
6	-0.53	29.16	23.43
8	-1.31	30.44	24.49
10	-1.25	31.86	25.62

Station No. 20 69 48.6 N 132 34.9 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	7.26	5.05	3.93
2	2.36	23.13	18.50
4	-0.05	27.33	21.96
6	-1.14	31.39	25.25
8	-1.33	31.36	25.23
9	-1.26	31.71	25.53

Station No. 21 69 45.2 N 132 37.4 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	5.72	16.96	12.95
2	4.82	24.87	19.71
4	0.37	29.97	24.06
6	-1.14	31.67	25.48
7	-1.24	31.83	25.61

Station No. 22 69 44.4 N 132 41.5 W 19/07/70

Depth	Temp.	Salinity	Sigma t
0	2.35	28.55	22.82
2	0.75	29.70	23.82
4	-0.44	30.94	24.87
6	-0.80	31.25	25.13

Station B 69 34.8 N 133 11.5 W 22/07/70

Depth	Temp.	Salinity	Sigma t
0	14.10	2.25	1.03
1	14.10	2.10	0.91
2	2.58	25.07	19.84
3	1.40	28.14	22.54
4	1.40	28.36	22.73

Station C 69 31.9 N 133 07.2 W 23/07/70

Depth	Temp.	Salinity	Sigma t
0	16.16	0.26	-0.83
1	16.06	0.82	-0.38
2	15.36	2.72	1.19
3	2.98	27.25	21.74

Station D 69 33.5 N 133 03.0 W 23/07/70

Depth	Temp.	Salinity	Sigma t
0	16.24	0.53	-0.63
1	16.26	0.55	-0.61
2	15.90	0.94	-0.26
3	9.81	7.68	5.78
4	2.72	27.69	22.12

Station No. 23 69 47.3 N 133 44.5 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	7.79	8.42	6.54
1	7.85	8.42	6.54
2	7.82	8.42	6.54
3	7.85	8.45	6.56

Station No. 24 69 41.5 N 133 37.5 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	6.25	7.43	5.88
1	6.28	7.07	5.58
2	6.20	8.02	6.34
3	6.26	15.05	11.85
4	1.80	26.58	21.28
5	1.78	26.60	21.30

Station No. 25 69 44.7 N 133 04.5 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	5.64	12.23	9.68
1	5.60	12.84	10.17
2	4.57	18.35	14.58
3	0.22	26.43	21.22
4	-0.88	28.61	23.00
5	-0.93	28.95	23.27
6	-0.97	29.18	23.46
7	-1.18	29.42	23.65

Station No. 26 69 52.2 N 133 35.7 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	4.54	18.63	14.80
2	4.07	19.59	15.60
4	-0.35	27.55	22.12
6	-1.20	29.73	23.91
8	-0.97	29.73	23.90
9	-1.04	29.79	23.95

Station No. 34 69 43.0 N 134 02.0 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	7.32	7.25	5.66
1	7.34	7.11	5.56
2	7.36	7.11	5.56
3	5.81	20.31	16.03

Station No. 33 69 47.4 N 133 04.0 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	6.55	6.52	5.13
1	6.53	6.52	5.13
2	6.62	6.50	5.12
3	7.70	14.49	11.32
4	5.54	21.58	17.06

Station No. 32 69 51.2 N 134 06.4 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	6.50	9.25	7.28
2	6.58	9.24	7.28
4	6.32	23.06	18.13
6	2.69	26.50	21.16
7	-0.95	30.52	24.54

Station No. 31 69 54.6 N 134 08.4 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	6.06	9.77	7.72
2	6.24	9.68	7.64
4	2.76	25.09	20.04
6	-1.30	30.67	24.67
8	-1.32	31.29	25.17
10	-1.55	31.62	25.43

Station No. 30 69 58.5 N 134 10.6 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	5.39	7.11	5.67
2	5.30	7.11	5.68
4	4.16	9.78	7.82
6	-1.22	28.81	23.17
8	-1.38	29.93	23.58
10	-1.58	30.80	24.77
15	-1.57	30.80	24.77

Station E 69 51.7 N 134 22.7 W 24/07/70

Depth	Temp.	Salinity	Sigma t
0	7.48	8.72	6.80
1	7.48	8.72	6.79
2	7.52	9.00	7.02
3	7.80	11.36	8.84
4	4.79	16.88	13.40
5	0.78	25.60	20.54
6	-0.70	29.39	23.62
8	-0.86	29.39	23.63

Station F 69 49.6 N 134 20.1 W 27/07/70

Depth	Temp.	Salinity	Sigma t
0	6.53	11.25	8.84
1	6.48	11.31	8.91
2	6.53	11.35	8.94
3	5.94	11.71	9.26
5	2.16	28.95	23.14
6	-0.27	29.16	23.42
7	-0.42	29.39	23.61

Station G 69 49.3 N 134 31.5 W 27/07/70

Depth	Temp.	Salinity	Sigma t
0	6.72	11.56	9.09
1	6.73	11.62	9.14
2	6.75	11.56	9.08
3	6.62	11.69	9.20
4	5.38	14.07	11.16
5	0.00	28.14	22.60
6	-1.03	29.65	23.84
7	-0.97	29.71	23.88

Station No. 38 69 51.4 N 134 42.0 W 27/07/70

Depth	Temp.	Salinity	Sigma t
0	7.31	8.80	6.88
2	7.31	8.90	6.95
4	7.93	10.88	8.46
6	-0.90	29.48	23.70
8	-1.20	30.47	24.51
9	-1.10	30.46	24.50

Station No. 37 69 48.4 N 134 40.9 W 27/07/70

Depth	Temp.	Salinity	Sigma t
0	6.77	11.24	8.86
1	6.90	11.27	8.85
2	7.16	11.26	8.82
3	7.67	11.55	9.00
4	5.22	21.79	17.24
5	0.79	23.16	18.59

Station H 69 48.4 N 134 40.9 W 23/08/70

Depth	Temp.	Salinity	Sigma t
0	7.36	23.80	18.94
2	6.68	25.89	20.58
4	3.42	29.64	23.71
6	3.06	30.22	24.16
8	3.08	30.42	24.32
10	3.08	30.62	24.46
12	3.05	30.70	24.52

Station No. 50 69 47.4 N 134 04.7 W 25/08/70

Depth	Temp.	Salinity	Sigma t
0	6.88	25.89	20.31
2	6.33	27.29	21.75
4	4.96	29.18	23.10
6	4.80	29.34	23.24
7	4.80	29.34	23.24

Station No. 51 69 50.0 N 139 09.9 W 25/08/70

Depth	Temp.	Salinity	Sigma t
0	6.88	24.94	19.56
2	6.00	26.03	20.52
4	2.23	30.86	24.67
6	1.59	30.79	24.65
8	1.58	30.86	24.70
10	1.58	30.91	24.74
13	1.54	30.91	24.74

Station No. 52 69 51.3 N 134 12.8 W 25/08/70

Depth	Temp.	Salinity	Sigma t
0	6.66	24.84	19.50
2	4.72	28.35	22.49
4	3.20	30.01	23.91
6	2.60	30.39	24.26
8	1.20	30.29	24.27
10	-0.04	30.50	24.50
15	-0.11	30.67	24.64

©
INFORMATION CANADA
OTTAWA 1972

**OBSERVATIONS OBTAINED ON A
MAGNAVOX SATELLITE NAVIGATION RECEIVER
IN HIGH LATITUDES
MAY 1971**

by
W.S. Huggett and A. Mortimer



ENVIRONMENT CANADA
Water Management Service
Marine Sciences Directorate
Pacific Region
1230 Government St.
Victoria, B.C.



CSS PARIZEAU

July 1970

PACIFIC REGION
CANADIAN HYDROGRAPHIC SERVICE
MARINE SCIENCES BRANCH
VICTORIA, B.C.
CANADA

A Report On Observations Obtained On A Magnavox
Satellite Navigation Receiver In High Latitudes

by

W. S. Huggett and A. Mortimer

MAY 1971

ABSTRACT

A Report on Observations Obtained On A Magnavox Satellite Navigation Receiver In High Latitudes

by

W.S. Huggett and A. Mortimer

From observations made at the optimum latitude for the number of satellite passes per day, the percentage of useful passes and their degree of reliability are assessed. The degree of reliability that can be expected from a satellite fix for real-time navigation decisions, without the benefit of off-line data processing, is shown. Comparisons are made between satellite fixes obtained in Latitude 70° N. and Latitude 49° N. The criteria for rejecting fixes is also discussed.

CONTENTS

	<u>Page</u>
Introduction	1
Data from Latitude 70° N.	2
Data from Latitude 49° N.	9
Conclusions	11
Bibliography	14
Illustrations	15

ILLUSTRATIONS

Figure

1. C.S.S. "Parizeau" (Frontispiece)
2. Map. Beaufort Sea
3. Summary of satellite passes (Latitude 70° N.)
4. List of displacements of position from each satellite (Latitude 70° N.)
5. Diagram of satellite elevations against displacement. (Latitude 70° N.)
6. Diagram of computation iterations against displacement. (Latitude 70° N.)
7. List of quality indices for passes with displacements >1930 m.
8. Graph of differences between actual and input ship's speed.
9. Graph of differences between actual and input ship's course.
10. List of displacements of position from each satellite. (Latitude 49° N.)
11. Diagram of satellite elevations against displacement. (Latitude 49° N.)
12. Diagram of computation iterations against displacement. (Latitude 49° N.)
13. Examples of Poor Fix Indices.
14. Graph of average interval between satellite passes for various latitudes.
15. Histogram - Linear displacement of satellite positions from Decca positions. (Latitude 70° N.)
16. Histogram - Displacement of satellite positions about N-S and E-W axes. (Latitude 70° N.)
17. Scatter Diagram - Satellite positions in Latitude 70° N.
18. Histogram - Linear displacement of satellite position from radar position. (Latitude 49° N.)
19. Histogram - Displacement of satellite positions about N-S and E-W axes. (Latitude 49° N.)
20. Scatter Diagram - Satellite positions in Latitude 49° N.

INTRODUCTION

The intense activity of the oil industry in Canada's far north, and in particular in the MacKenzie River delta area, has resulted in a greatly increased scientific interest by the Canadian Government in this area. As part of this interest the Polar Continental Shelf Project (PSCP) established a Decca Lambda chain off the Delta to give precise electronic positional coverage over most of the Beaufort Sea. The chain was established in 1969 for a period of three years, by which time it is thought that most of the work in the Beaufort Sea will have been completed. To take full advantage of the Decca Lambda chain, the Canadian Hydrographic Service, in 1970, sent two major ships, the BAFFIN and PARIZEAU, to carry out hydrographic and geophysical surveys on the continental shelf off the MacKenzie River delta. Following the initial season, the PARIZEAU was further committed to a four year programme of hydrographic and geophysical surveys in the Western Arctic.

In July, 1969, the PARIZEAU was fitted with a Magnavox 702 receiver with automatic acquisition and coupled to a Hewlett-Packard 2115 computer. (See Fig. 1) The program in use, supplied by Magnavox, was MAPS-70065. No actual tests on the accuracy of the system had been carried out, other than cursory checks by deck officers on the ship. In June, 1970, prior to leaving for the Arctic, the launch crews and ship's officers were given training in steering on hyperbolic lines or 'lanes' as they are known.

To do this a Decca mini-fix chain was temporarily established close to Victoria to provide 'lanes' for the training period. It was not calibrated nor was a lattice chart drawn up for the area. Despite being unable to check the Satellite navigation system at this time, it was noticed that the satellite receiver was very sensitive to ship movements. Unless the ship was maintained on a steady course and at a steady speed during a satellite 'lock-on' by the receiver, the position given would be considerably in error. On the passages to and from the Arctic the course and speed of the ship was maintained during all 'lock-ons' of satellites. In spite of this precaution there was an unacceptable discrepancy between the satellite positions and the actual positions. The positions were put on plotting sheets, (Contoured Position Plotting Sheet, USNHO) where it is possible to plot a position to within 340 m. It should therefore be possible to identify errors >3400 m and reject those positions that exceed this amount. The ship's actual position could only be established through plotting all fixes, and rejecting those that did not fit. This practice meant that the ship's plotted position was anywhere from eight to twelve hours behind her actual position. This inconsistency among the satellite positions prompted the following enquiry and observations.

Data from Latitude 70° N.

The Decca Lambda 6F chain off the mouth of the MacKenzie River was established by Computing Devices of Canada Ltd. (CDC), and is maintained and operated by

them for PCSP during the periods the positioning system is required. The chain consists of a master station on Hooper Island and two slave stations, one on Herschel Island to the west and one on Point Atkinson to the east. (see Fig. 2) This configuration allows for only a small area north of the master station to have an accuracy of ± 50 m or less. The working area of the PARIZEAU, to the west of the master station, was calculated to have a maximum probable shift of ± 120 m in the pattern. Before being used the chain was calibrated by two methods available to us: (1) by using the mini-fix chain established in MacKenzie Bay, and (2) by intersection of the ship from two shore stations.

In MacKenzie Bay, a hyperbolic mini-fix chain had been established to provide positioning coverage of the Red base line extension of the Decca Lambda Chain. The mini-fix chain also covered part of the area where the satellite positions were obtained. This mini-fix chain, having been calibrated prior to use, therefore, provided a reasonable method of calibrating the Decca Lambda Chain. Although the estimated pattern shift of the mini-fix chain in the calibration area was ± 35 m, and as such did not meet the arbitrary criterion of a ratio of 10:1 for calibration of the Decca Lambda, (the Decca Lambda pattern shift being ± 120 m), the results of the calibration proved satisfactory. Forty simultaneous positions from the mini-fix and the Decca Lambda were compared, and the mean differences in Decca Lambda lane counts were applied as corrections to the Decca Lambda readings. To further check the Decca Lambda pattern, twenty

positions of the ship were intersected by theodolite angles observed from two known shore stations. The positions given by intersection were compared with simultaneously observed Decca Lambda readings. The corrections obtained from the intersection method of calibration differed only slightly (± 0.007 Decca Lambda lane widths) from the corrections obtained by the mini-fix method. The Decca Lambda chain was monitored for short term changes in pattern at a receiver in Tuktoyaktuk. Deviations of the Decca Lambda lane count from the known lane count of the Tuktoyaktuk monitor receiver were also applied as corrections to the Decca Lambda readings used with the satellite observations.

The area to be surveyed after MacKenzie Bay was completed was the area north of MacKenzie Bay and mid way between the Master and Green slave on Herschel Island (see fig. 2). This was fortunate as the hyperbolic lines in this area are, for all practical purposes, straight lines, and ideal for checking the satellite navigation equipment. Another fortunate aspect of this area was that the hyperbolic lines all ran in a north-south direction, a direction in which errors in the estimated ship's speed has the maximum effect on the position.

During the recording of the satellite navigation data, the ship was running bathymetric lines and was towing a magnetometer. Normally, the ship was kept on a hyperbolic lane and the bathymetric graph was marked at every intersecting lane. While acquiring the satellite data, however, the Decca Lambda position was recorded every two minutes as soon as the receiver 'locked-on' to a satellite. The interval used was even minutes, with the time being given by a crystal controlled electronic clock.

The observations were started on day 245 (Sept. 1) at 1800 gmt, and carried on continuously to day 248 (Sept. 4) at 1800 gmt. The speed of the ship was given by the timed crossings of the lanes, and was the average taken over a span of an hour. The two minute readings were not used, other than as a check, the short time base giving widely fluctuating speeds. The error in our speeds used for the computations was in the region of ± 1 kt. It was also noted at this time that the estimate of the speed of the ship by the officer of the watch was in the region of ± 6 kts. in error.

The differences between Clarkes spheroid (1866), using the North American Datum (1927) and the geocentric spheroid and datum used by the USN Satellite System are small from the navigational point of view. The general effect of this datum shift in our areas of operation was (1) in the Beaufort Sea, $-0.26''$ Difference of Latitude (D. Lat.) and $+11.93''$ Difference of Longitude (D. Long.), and (2) in the Juan de Fuca Strait, $-0.81''$ D. Lat. and $5.25''$ D. Long. These datum shift figures when applied to the comparison positions moved them 130 metres (in the Beaufort Sea) and 111 metres (in Juan de Fuca Strait) closer to the vector mean position given by satellite. The datum shifts were calculated using transformation equations (Heiskanen and Moritz, 1967, p. 207 and Vincenty, Journal of Geophysical Research, Vol. 71, p. 2620) and the Smithsonian Astrophysical Observatory (Viers, 1966, 1967) C-7 geodetic parameter system.

The Alert program, which gives the rise times, the times of closest approach and the elevations of a particular satellite throughout the course of a day

for a particular place, was run for all five satellites. During the time of the survey, 202 passes could be expected - an average of one every twenty-one minutes.

Out of the total number of available satellite passes, the receiver picked up 100 passes (49.6%). The Alert program gave thirteen passes having a greater elevation than 80° , and no passes with an elevation of less than 10° . This agrees with what we obtained, all recorded elevations coming within the range 10° - 80° . Of the 100 satellites picked up on the receiver, thirteen ended in an error message being given. Eight error messages were for no solution, that is, the convergence criteria were not met within 20 iterations, the most likely reason being that the satellite was at an elevation greater than 80° or, possibly, less than 10° . Four error messages were for insufficient doppler data, most probably caused by interference from other satellites that were above the horizon at the same time. The remaining error was also a solution error which occurred while trying to solve for frequency, latitude or longitude. Two positions given had errors greater than 6000 m (abt. 3 nautical miles), probably due to interference from other satellites.

From the available satellites eighty-seven (43% of total alerts) positions were obtained in four days. Five of these positions were displaced from the Decca position by more than 3500 m (abt. 2 n miles) and therefore obviously in error. The remaining 82 positions were analyzed. They gave a mean position 200 m by 264° away from the Decca comparison position. The standard

deviation about the north-south axis was ± 784 m, and ± 563 m about the east-west axis. Since the distribution of errors is qualitatively gaussian, it is possible to assume that an ellipse of error (68% reliability) exists about a position, having a semi-major axis of 965 m. However, a navigator requires at least 95% reliability, in which case, for gaussian errors, the critical dimension of the ellipse is 1930 m (abt. 1 n mile), (see fig. 3).

In these northern latitudes it is possible to obtain 28 positions or more a day (see fig. 4) or an average of about one position every 51 minutes. However, the longest interval between passes yielding positions was 3 hours 34 minutes, and other long intervals were 1h.48m and 1h.46m. Under these conditions, a navigator might be able to detect fixes which are in error by more than 1 n mile (1852 m) and consequently discard them. Using only the data that gave positions of <1930 m displacement from the Decca position the maximum likely error in position would be ± 1146 m (95% reliability).

Various methods were used to find out if there was a method of assessing the reliability of any one position. To see if there was bias in the results; a scatter diagram (see fig. 17) was drawn. There appears to be a slight bias to the west, the mean for all positions is D. Lat.-21 m, D. Long.-199 m, and for all positions <1146 m the mean is D. Lat.+103 m, D. Long.-93 m. The difference between the NA 1927 datum (on which the Decca Lambda is based), and the satellite datum for the survey area, is D. Lat.-7 m, D. Long.-130 m, leaving a net bias of approximately 100 m in the latitude. This figure is less than the ± 120 m error that could have been present in the Decca chain.

Satellite elevations were plotted against the displacement of each position

(see fig. 5) and no discernable pattern was present. The number of iterations was also plotted against the displacement of each position (see fig. 6). Again no discernable pattern was present.

Of the eleven positions with a displacement greater than about one n mile, 6 had good doppler counts with ≤ 6 iterations, with the exception of one position that took 14 iterations, and two from satellites with elevations $>70^\circ$ (71° and 80°). However, the elevations of the other four positions were 15° , 18° , 21° and 27° . Two positions had missed two-minute doppler counts near the closest approach (C.A.) of the satellite, and one had an asymmetric doppler count. However, four positions within one standard deviation had asymmetric counts (from the receiver locking-on immediately after having given a position). Two of the positions had no print-out of the doppler count, but one had 11 iterations on an elevation of 19° and the other 5 iterations on an elevation of 39° (see fig. 7).

There thus appears to be no sure way of telling a good position from a bad position using only information from the satellite position tabulation. Positions having asymmetric dopplers, missed dopplers near the closest approach of the satellite, and satellite elevations $>70^\circ$ and $<25^\circ$, when in high latitudes, should be treated with caution. From our experience, 68% of all positions will be within 965 m if accurate input of speed made good over the ground, and true direction of travel are available. To give some idea of the error resulting from an erroneous estimate of either speed or course, figures 8 and 9 show differences that are obtained by computing fixes using differing values for course and speed.

Data From Latitude 49° N.

In April, ship time was made available and from day 111 (April 21) at 0400 gmt to day 113 (April 23) at 1600 gmt, additional satellite fixes were obtained. These positions were not controlled by an electronic positioning system, but by the ship's radar, a Decca 629 with an accuracy of about 100 m in the ranges up to and including the 6 mile range, and about 200 m for the 12 mile range (1% of full scale). All targets were within 12 miles, and the plotting error on the chart was <100 m. The maximum error to be expected from a radar position (by distance measurement from three or more points) would have a displacement of less than 300 m. This displacement figure is larger by a factor of almost three than that of the control used in the Arctic.

The ship's position was plotted every twenty minutes by three or more radar distances to prominent points. The ship's speed from these plots could be in error by ± 0.38 kts. (at 8 kts.) and the course by $\pm 3^\circ$. This speed error is quite large, and on the east-west courses that were mainly being run, could amount to an additional error in position of about 100 m, and the course error could also amount to an additional 100 m.

From the Alert program 83 satellite passes were forecast for the time period, an average of one every 43 minutes, and the receiver monitored 62 (75%) of the passes. Of these, 40 (48.2%) gave positions, the other 22 ending up in

error messages. These figures may be on the low side as some time was spent on recomputing the positions with different inputs of speed and course. In any event, although 25% more passes were monitored by the receiver in latitude 49° than in the Arctic, only 6% more positions were obtained. This is contrary to what one expects, and in part may be accounted for by the number of satellites that are above the horizon at any one time in the high latitudes and thus are interfering with each other. Another reason may be the fact that a new program from Magnavox - No. 70356 - was used.

Of the forty positions obtained, seven were in areas outside of radar distance and hence have no comparison position, and the remaining five were being tracked at the time of major course alterations by the ship. Twenty-eight positions (see fig. 10) were actually compared with radar positions, and the mean of these positions was displaced 228 m by 253° from the radar position, with possible maximum displacement of 1522 m (95% reliability). There were only four positions with displacements greater than 1100 m and the largest was only 2121 m. All these positions fall into the hard-to-detect area, and the percentage - 14% - agrees with the results obtained in the Arctic. Of the four, two would be discarded because of their elevations - 84° and 7° , but the remaining two with elevations of 52° and 38° , iterations of 2 and 3 respectively, and all with good doppler counts show no reason for having large displacements. Scatter plots of the elevations (see fig. 11) and iterations (see fig. 12) show no pattern. Conversely, a low elevation, with asymmetric dopplers can provide an acceptable position (see fig. 13).

The major difference between the positions obtained in latitude 70° and those in latitude 49° was the absence of any positions over 2200 m in error in the lower latitude. Possibly the new program contributed to this state, but the major factor would seem to be the lesser number of satellite passes each day, thereby giving less interference to each other. The large number of error messages obtained, however, would not seem to support this hypothesis. Some of the error messages undoubtedly are the result of tracking satellite 30100 (which has very weak transmissions), whereas in the high latitudes where there is a greater chance of more than one satellite above the horizon at any one time, the weak 30100 was probably drowned out by the more powerful satellites. A breakdown of the error messages showed eleven passes having no solution, i.e. no convergence within twenty iterations; three had errors which occurred when solving for frequency, latitude or longitude; three had insufficient message data (normally occurring after tracking 30100); and four were where the majority vote resulted in an illegal BCDX3 fixed parameter. There were no errors from insufficient doppler data and none from receiving an incorrect variable parameter.

Conclusions

1. Errors in position of less than 3500 m (abt. 2 n miles) are extremely hard to detect from satellite data alone, and there appears to be no way of making an intelligent decision immediately on the accuracy on any one position.

Errors >3500 m (about 6% of the positions) can be detected by keeping a plot of the ship's position and knowing fairly accurately the ship's speed and course, and thus being able to make a decision on the accuracy of the position. The majority of the positions (68%) are within 930 m of the true position with a mean position displacement of 476 m. This leaves 18%, or one in five, of all positions in the >930 m to <3500 m error range, and it is because of this that the navigator must use the utmost caution. On large vessels such as super tankers 68% of all positions will plot within three ship lengths, but 18% will plot up to 2 n miles distant. In areas such as the Beaufort Sea with its numerous 'underwater pingos', navigating by satellite position alone would be an extremely hazardous undertaking. Vessels should, when navigating by satellite, attempt to keep clear of all dangers by at least two nautical miles.

2. When navigating by satellite positions the ship must be kept on a steady course with a steady speed for as long as the receiver is 'locked-on' to the satellite. Any alteration in either the course or speed of the ship will result in either an error message being promulgated or an erroneous position.

3. It is not good enough to initialize the program with inputs of the speed and course to the nearest 1/2 knot and 10° respectively. Errors of 1/2 knot in the speed can result in errors of 500 m in position on N-S courses, and 10° in course can result in the same error when on E-W courses. There does not seem to be much advantage to having a log and gyro input of the speed and the

course into the computer, as the true speed and course over the ground is what is required.

4. The criteria that governs whether a satellite position should be used or discarded are indefinite. Generally, passes with elevations $>70^\circ$ and $<10^\circ$, asymmetric dopplers, and missed dopplers near the closest approach of the satellite could cause an error in the position. These indices are not always reliable, but from the results of this survey they would eliminate about 40% of the positions in the hard-to-detect error range.

5. The number of positions obtainable from satellites in high latitudes is about the same as those obtained in the middle latitudes.

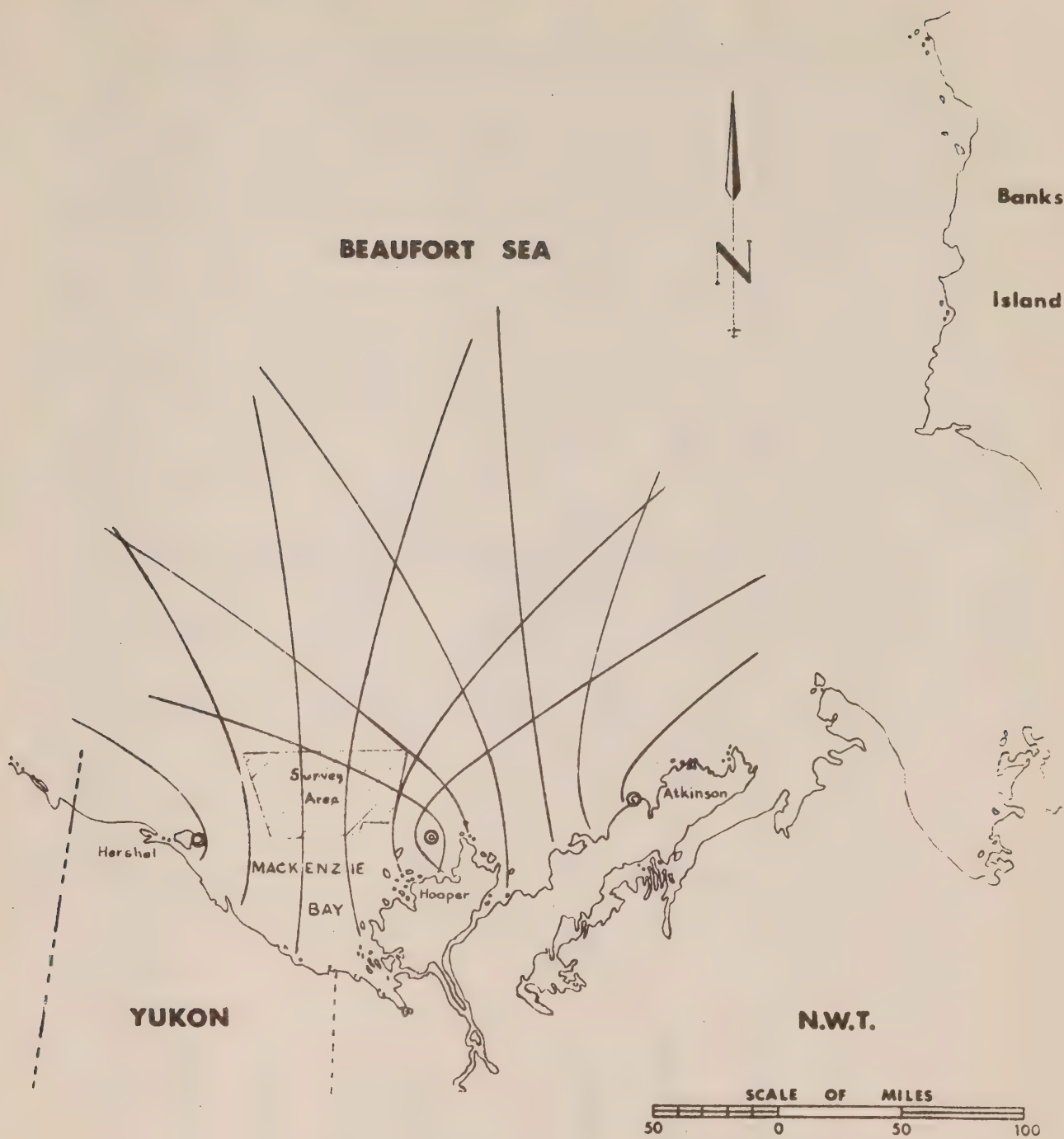
6. The datum difference between NA 1927 and the geo-centric datum may be neglected from a navigational point of view. The difference, in most cases, is hardly plotable on charts.

7. Maintenance on the Magnavox receiver and H.P. 2115 computer have been minimal, and in no instance has there been any down-time when the instruments have been in use.

BIBLIOGRAPHY

- Budlong, K.S. Alert Calculations for the Satellite Navigation System.
Unpublished Manuscript. Bedford Institute, Dartmouth, N.S.
- Hittel, Alex., Kouba, Jan., Krakiwsky, Edward J., Wells, David E., Eaton, R.M. Report on a Doppler Satellite Positioning Experiment in Canada.
Paper given to Canadian Institute of Surveying, Annual Meeting, Ottawa, 1971.
- Hittel, A. and Kouba, J. Integration of Satellite and Decca 12F Survey Systems. Shell Canada Limited, Calgary, 1971.
- Moody, Alton B. "Satellite Systems for Geophysical Exploration at Sea".
The Journal of the Institute of Navigation. Vol. 23, No. 4 Lenden, 1970.
- Ross, D.I., Wells, D.E., Douglas, G.R., and Eaton, R.M. Navigation at the Bedford Institute. Unpublished manuscript. Bedford Institute, Dartmouth, N.S., 1970.
- Stansell, Thomas A. Jr. "The Navy Navigation Satellite System: Description and Status". Navigation. Vol. 15, No. 3. Washington, 1968.
- Stansell, Thomas A. Jr. "Using the Navy Navigation Satellite System".
Navigation. Vol. 17, No. 2. Washington, 1970.
- Wells, D.E. and Ross, D.I. Experience with Satellite Navigation Equipment During Summer 1968. Unpublished manuscript. Bedford Institute, Dartmouth, N.S.
- Wells, D.E. ed. Cruise Report No. 69-022. C.S.S. Baffin April 28 - May 7, 1969. Bedford Institute, Dartmouth, N.S.
- Wells, D.E. and Krakiwsky, Edward J. Use of Satellite Doppler Observations to Determine the Offset of the Origins of Geodetic Datums from the Geocentre.
Paper given to Canadian Institute of Surveying, Annual Meeting, Ottawa, 1971.

ILLUSTRATIONS



DECCA LAMBDA CHAIN

Fig. 2

	30130	30120	30140	30180	30190	TOTAL
Number of passes from Alerts	40	41	40	40	41	202
Number of passes monitored						102
Number of error messages						13
Number of error positions						2
Positions obtained	29	23	16	14	5	87
With displacement >3500 m	1 3%	1 4%	2 12%	1 7%	--	5 6%
With displacement <3500 m and >1100 m	2 7%	2 9%	4 25%	3 22%	--	11 13%
With displacement <1100 m	26 90%	20 87%	10 63%	10 71%	5 100%	71 81%

Fig. 3

<u>Day</u>	<u>30130</u>	<u>30120</u>	<u>30140</u>	<u>30180</u>	<u>30190</u>
245	235	431 458	380 2830		
246	37 852 300 619 364 596 566	3566 1022 332 258 829 271 1644 653 377 802	256 228 3546 3168 1997 290	564 321 452 1325	297 475
247	5705 320 2489 684 992 371 139 467 639 677 120 186 949	740 354 516 584 1354 56 (31980) 451	176 197 3249 738	374 1148 756 143 183	191 264
248	614 547 116 376 427 62 807 2501	126 303 98 589	356 610 213	328 2600 128 416	599

List of displacements of positions
from each satellite

* not used in calculations.

Fig. 4



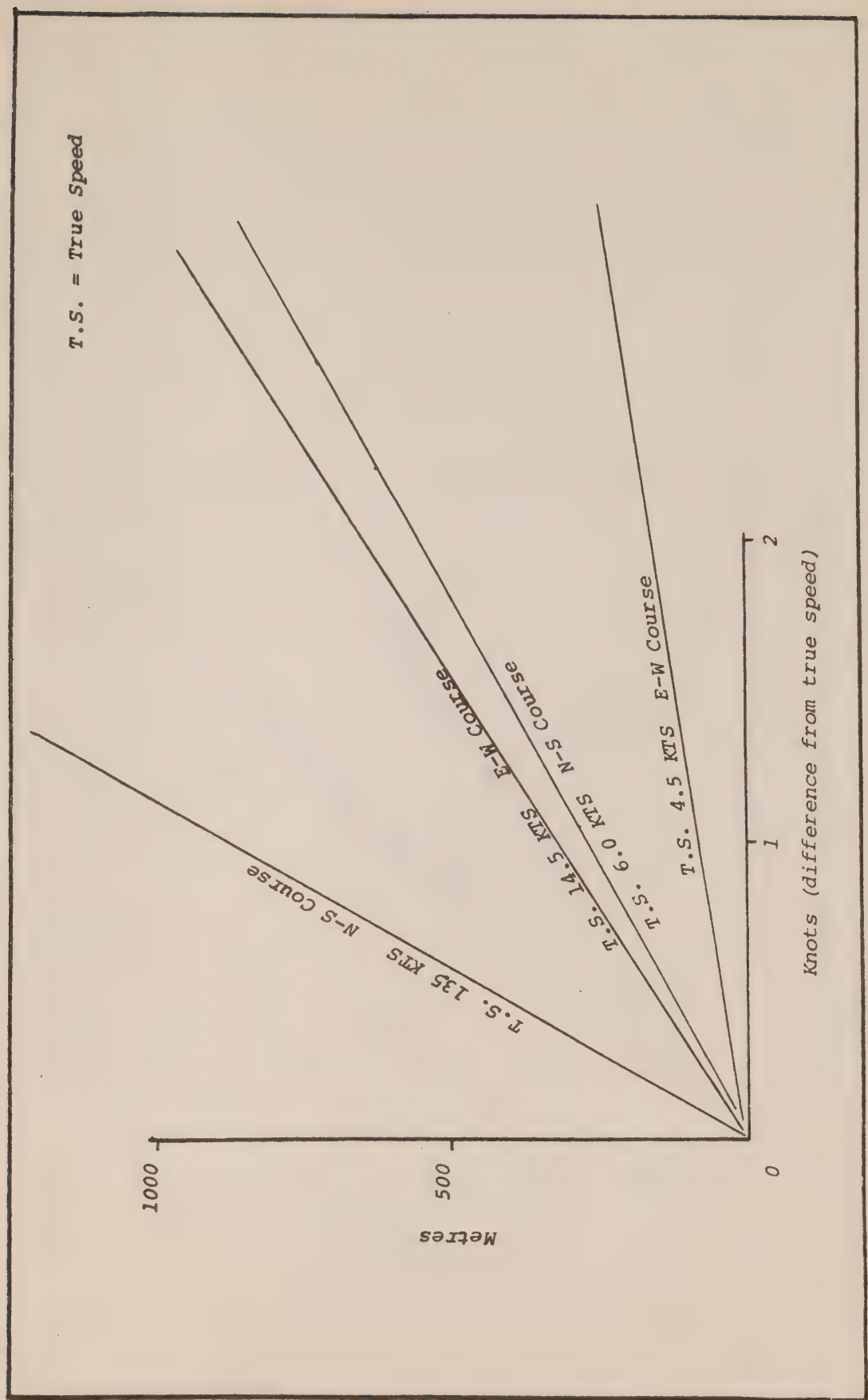
Fig. 5



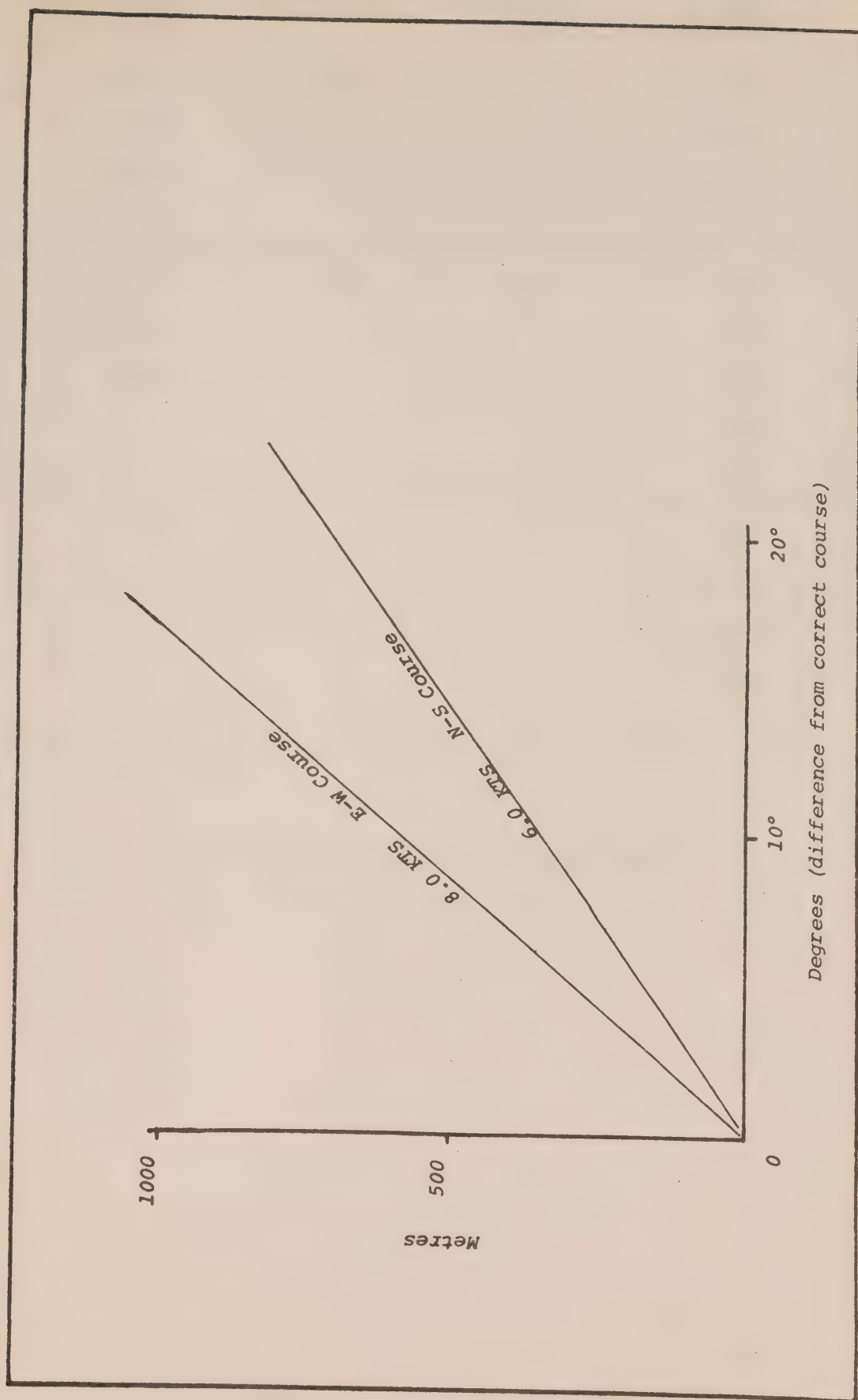
	<u>Doppler Count</u>	<u>Iterations</u>	<u>Elevation</u>
1997	good	3	21°
2489	good	6	18°
2501	good	14	15°
2600	some missed	4	58°
2830	asymmetric	15	29°
3168	no print out	5	39°
3249	good	3	27°
3546	some missed	6	67°
3566	no print out	11	19°
5705	good	6	71°
31980	good	12	80°

Table showing positions with error > 1930 m

Fig. 7



Difference between actual and input speeds.



Difference between actual and input ship's course.

Fig. 9

<u>Day</u>	<u>30120</u>	<u>30130</u>	<u>30140</u>	<u>30180</u>	<u>30190</u>
111	262	336		383	463
	150			409	477
	1325			1084	253
<hr/>					
112	174	630	216	258	160
	1563			594	656
	1651			537	
				467	
<hr/>					
113	126		237	390	625
				2121	
				321	
				272	
<hr/>					

List of displacements of positions
from each satellite

Fig. 10

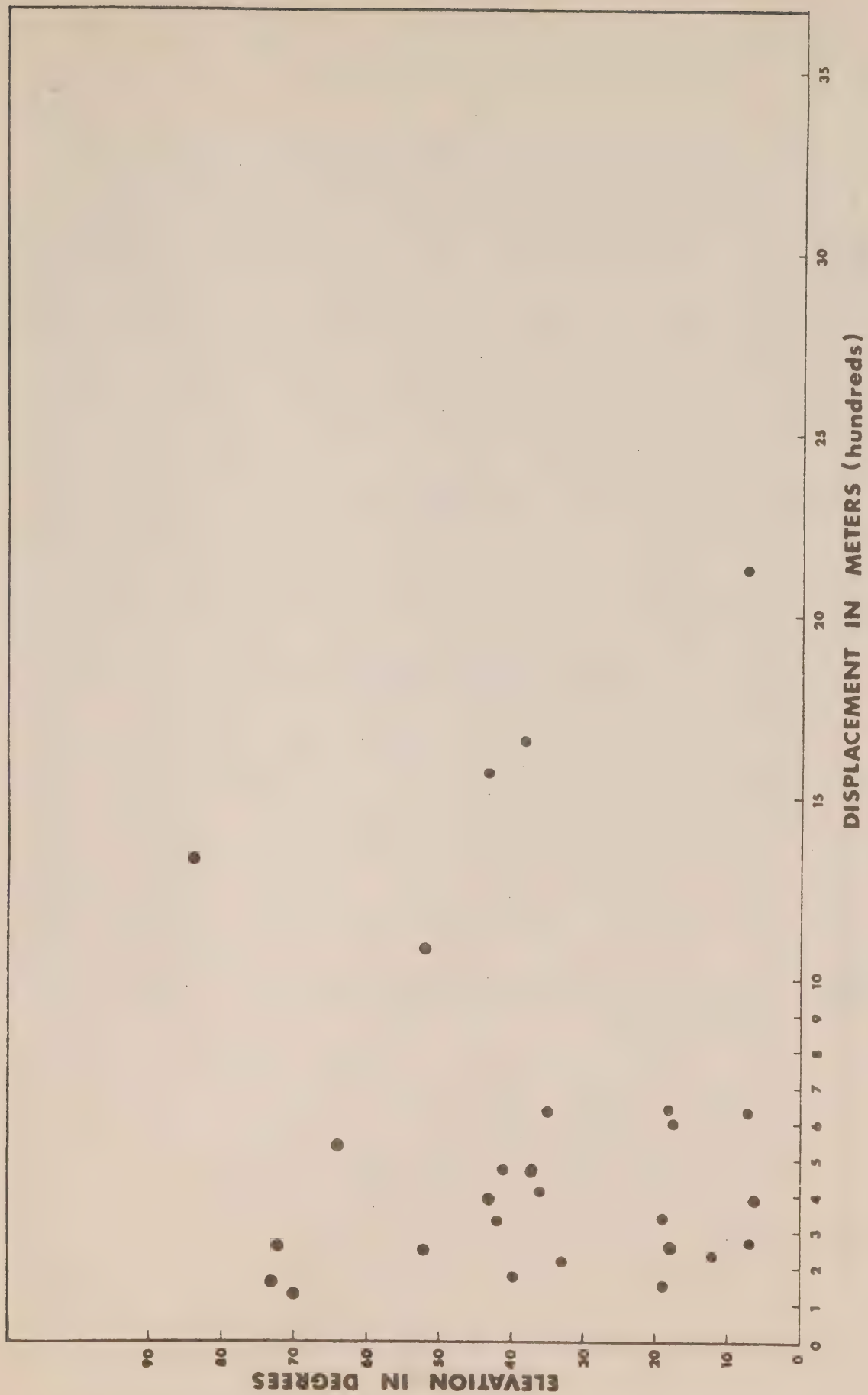


Fig. 11

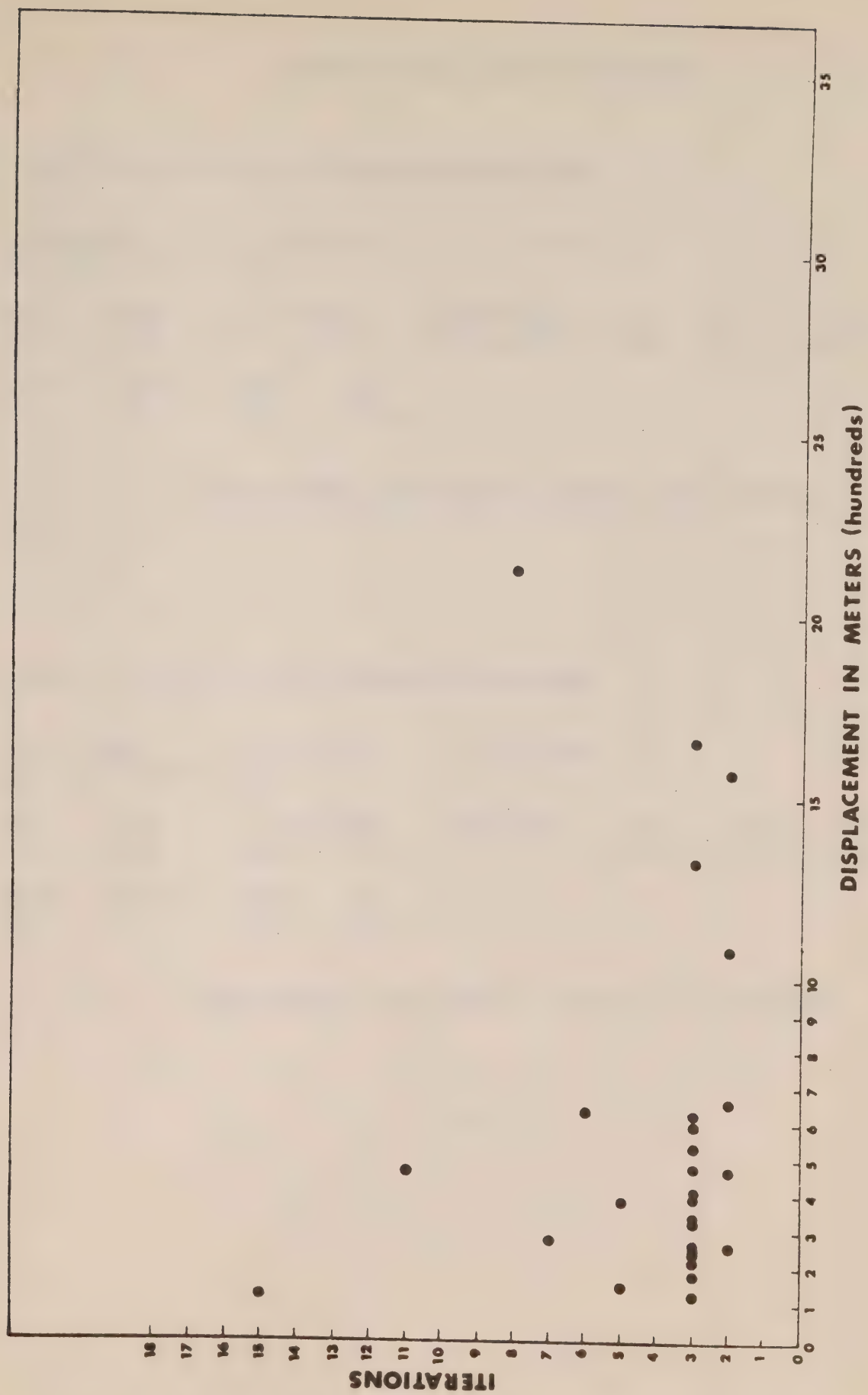


Fig. 12

EXAMPLES OF POOR FIX INDICES

000000????????????????00000000000000000000

↑↑

2.1567978 -11.526157 11.726212
SAT FIX MAPS-N-70356

DAY	TIME	LATITUDE	LONGITUDE	ANT	HDG	SPD
112	1004	048 30.229 N	124 39.418 W	+0018.	331.0	7.000

ITER	ELEV	GEOM	SAT
06	07	S-W	7464.03

Displacement from Radar Position 630 metres

000????????????????0000000000000000000000

↑↑

-0.3738829 -1.7215032 1.7616362
SAT FIX MAPS-N-70356

DAY	TIME	LATITUDE	LONGITUDE	ANT	HDG	SPD
113	0326	048 13.950 N	124 47.776 W	+0018.	247.0	5.000

ITER	ELEV	GEOM	SAT
08	07	S-W	7462.72

Displacement from Radar Position 2121 metres

Fig. 13

AVERAGE INTERVAL BETWEEN SATELLITE
PASSES FOR VARIOUS LATITUDES
(ELEVATIONS $> 10^\circ$ & $< 80^\circ$ AT C.A.)

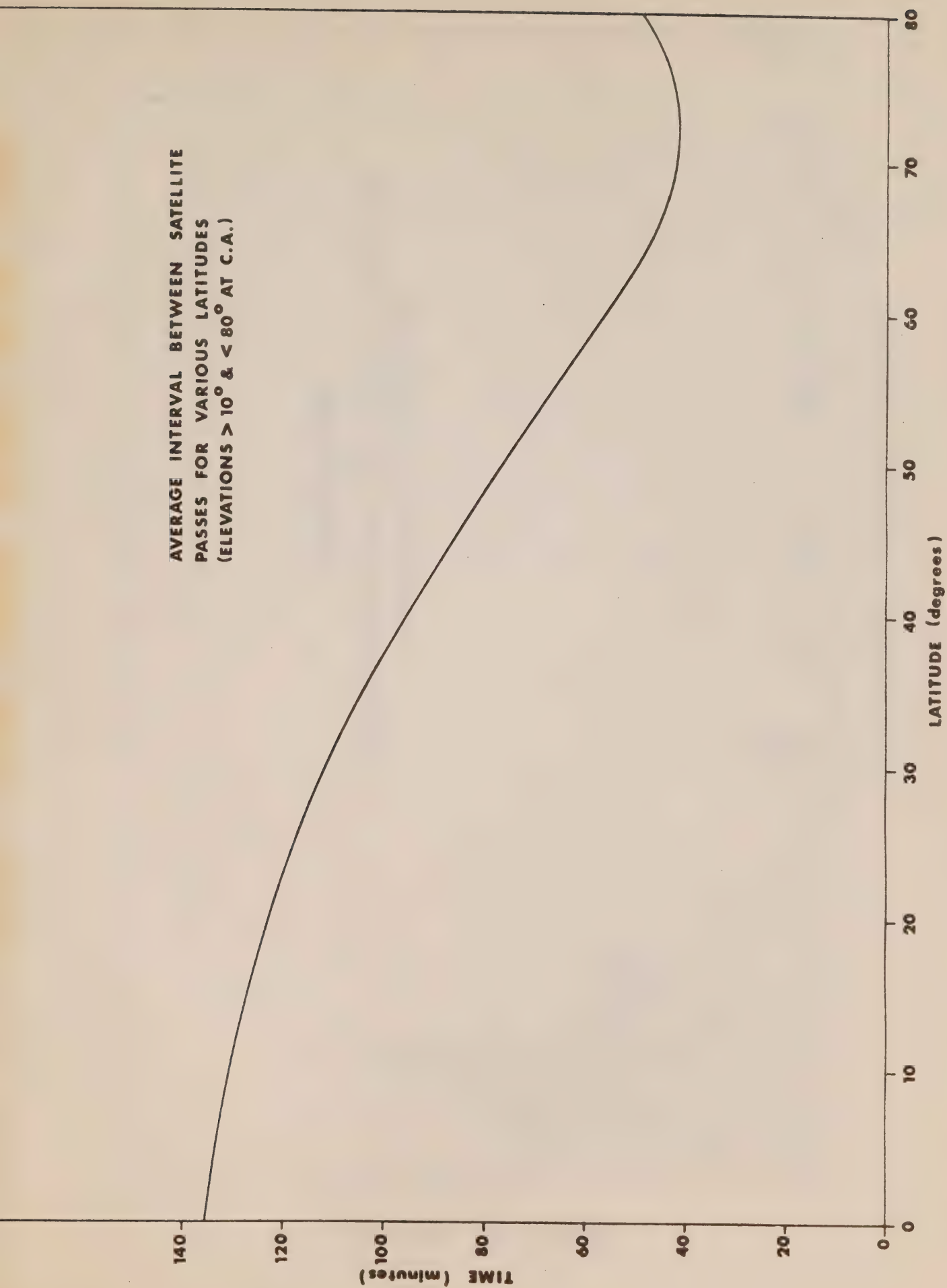


Fig. 14

HISTOGRAM

LINEAR DISPLACEMENT OF SATELLITE POSITION
FROM DECCA 6F POSITION

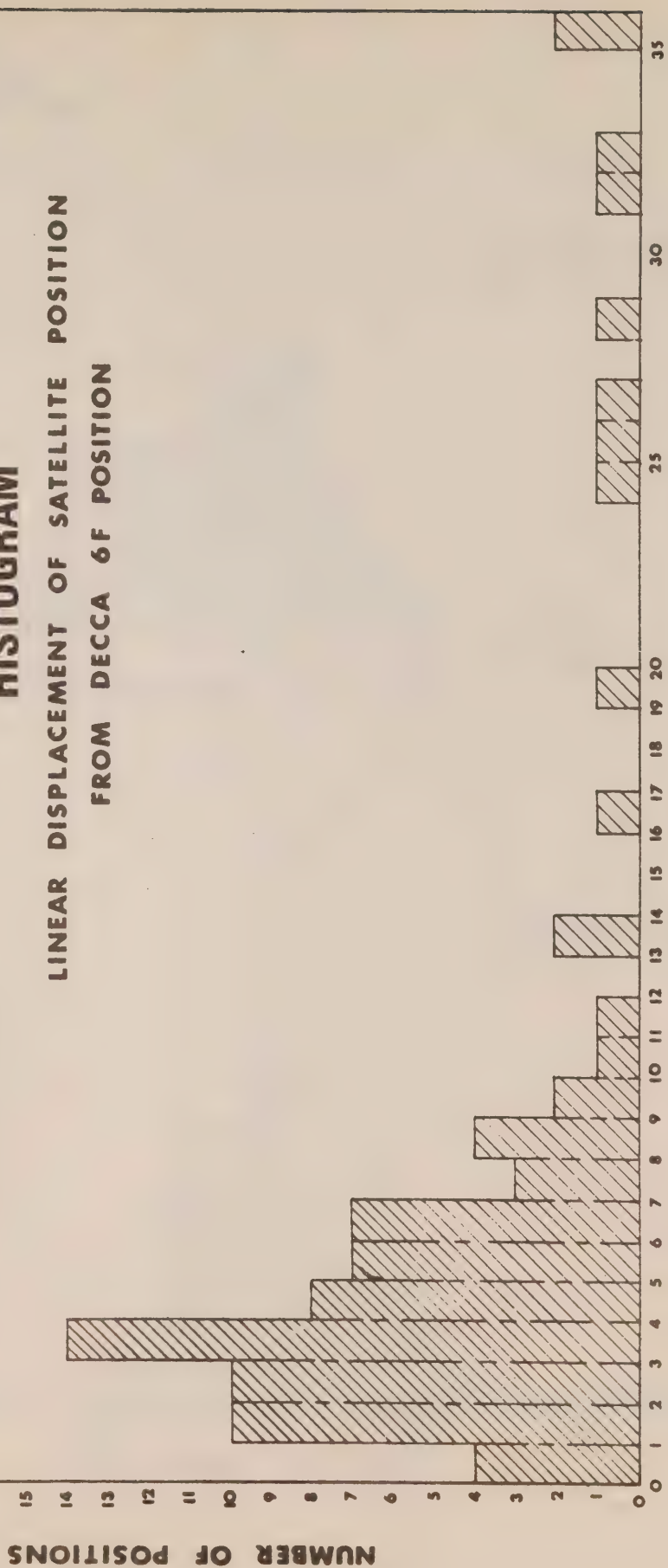


Fig. 15

BEAUFORT SEA

**DISPLACEMENT OF
SATELLITE POSITIONS
ABOUT N/S & E/W AXIS**

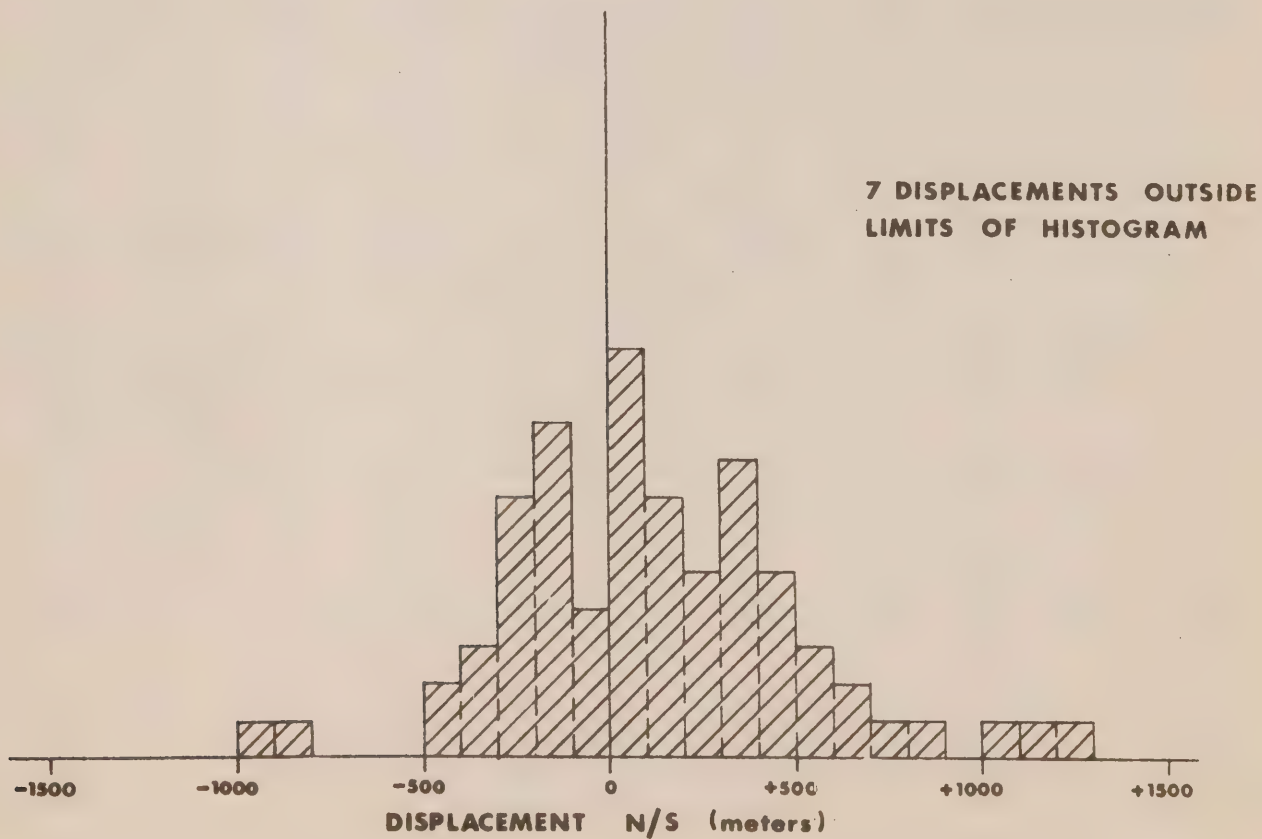
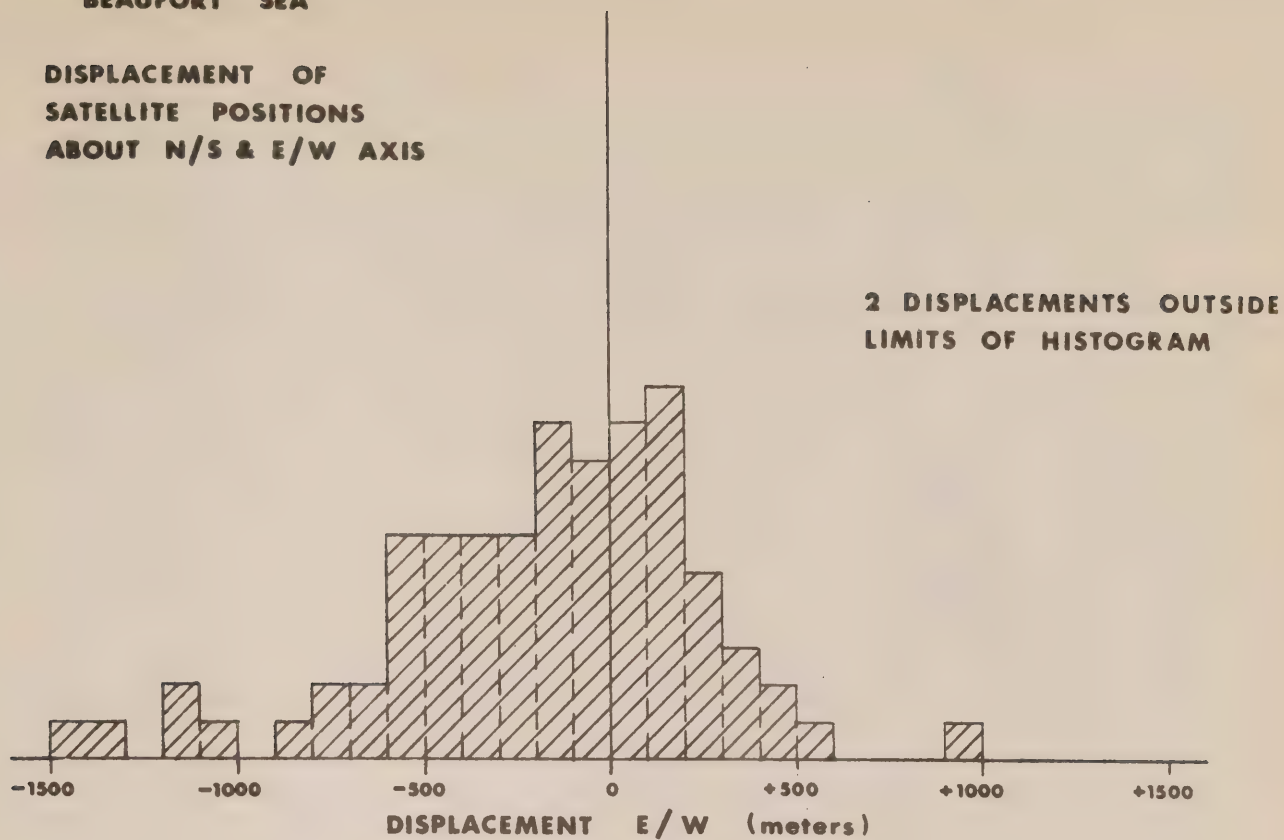


Fig. 16

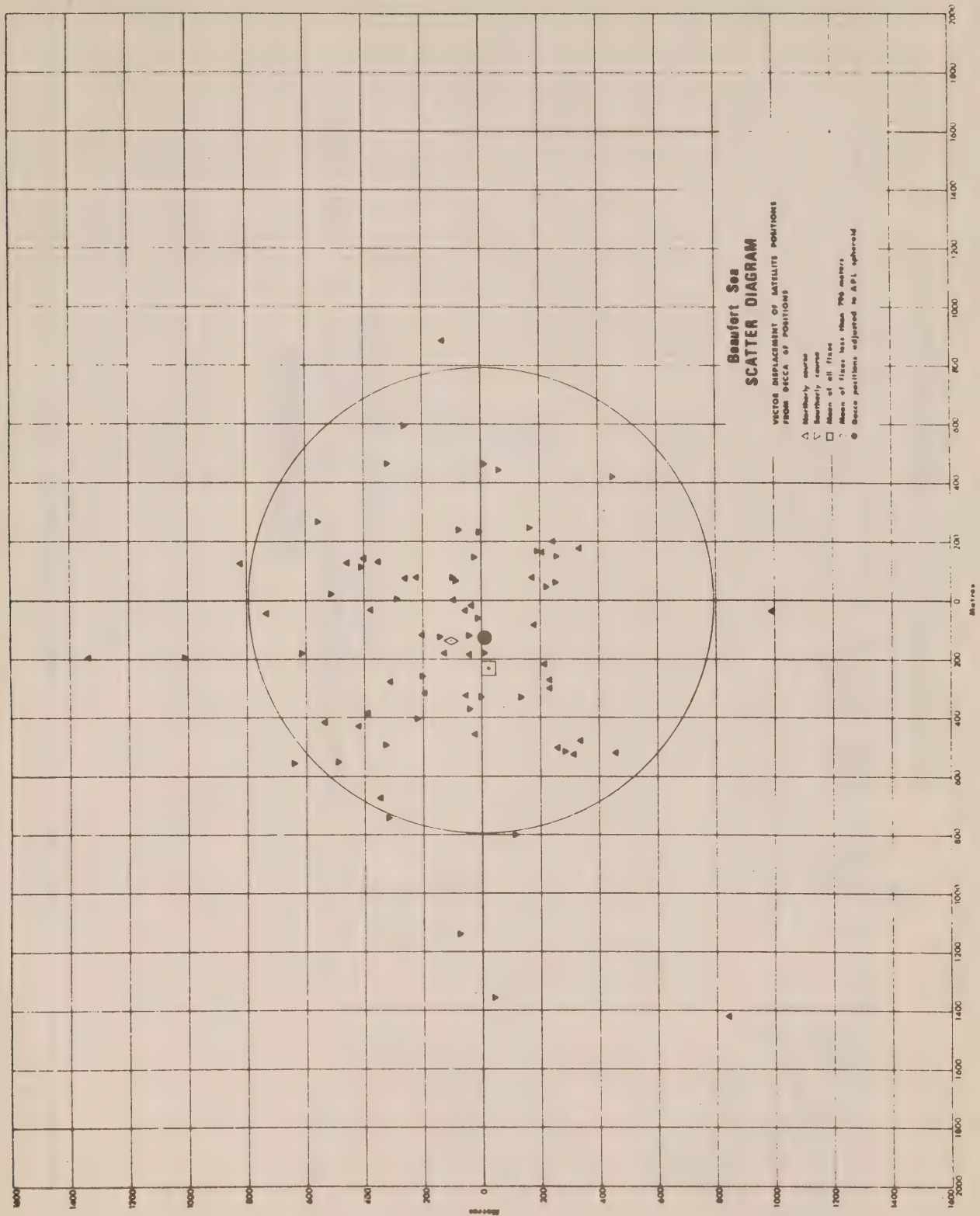
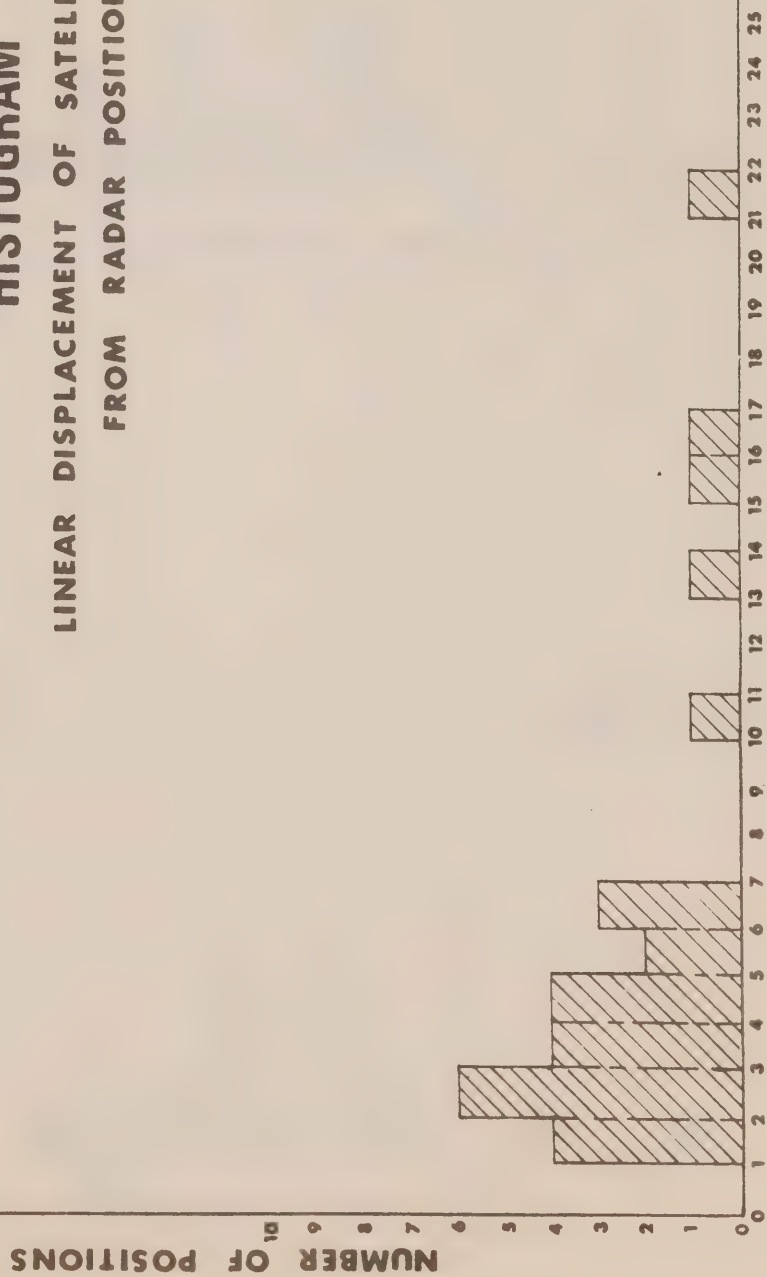


Fig. 17

HISTOGRAM

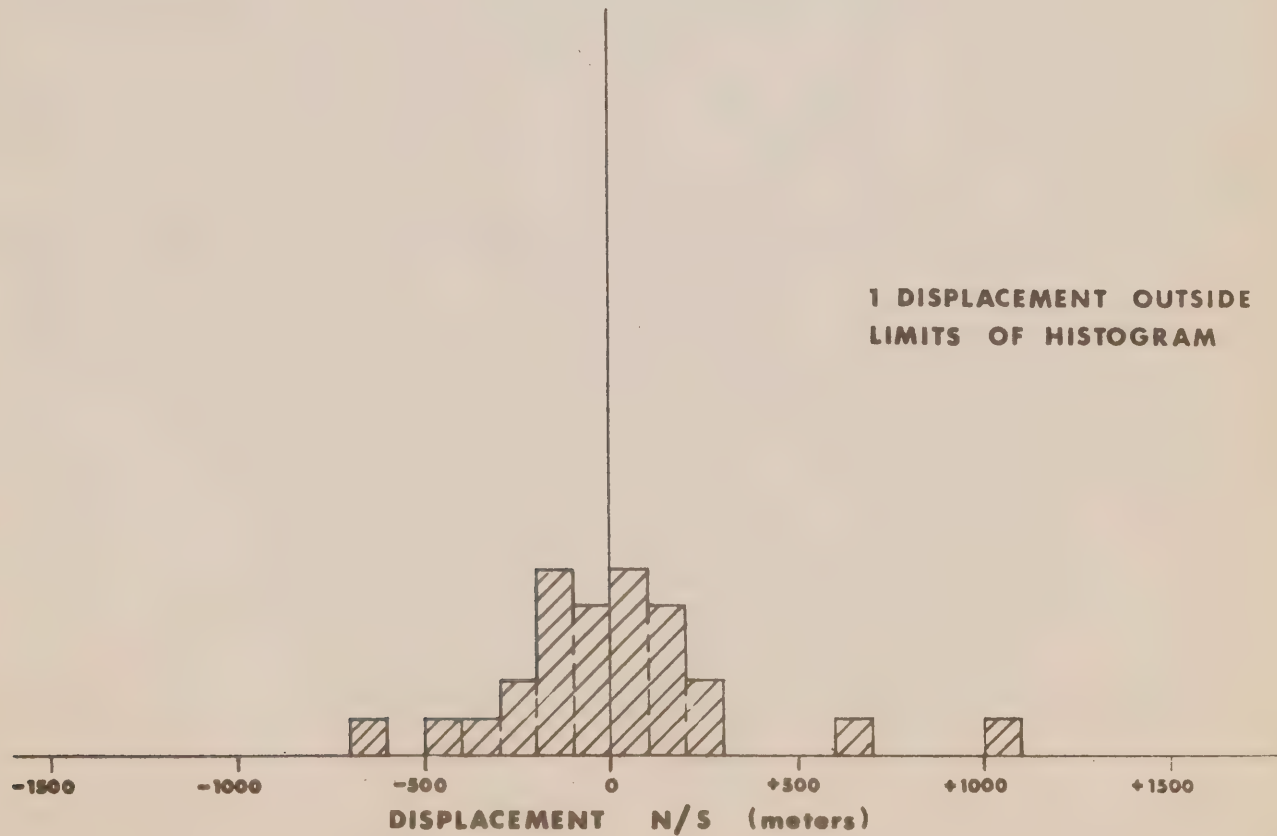
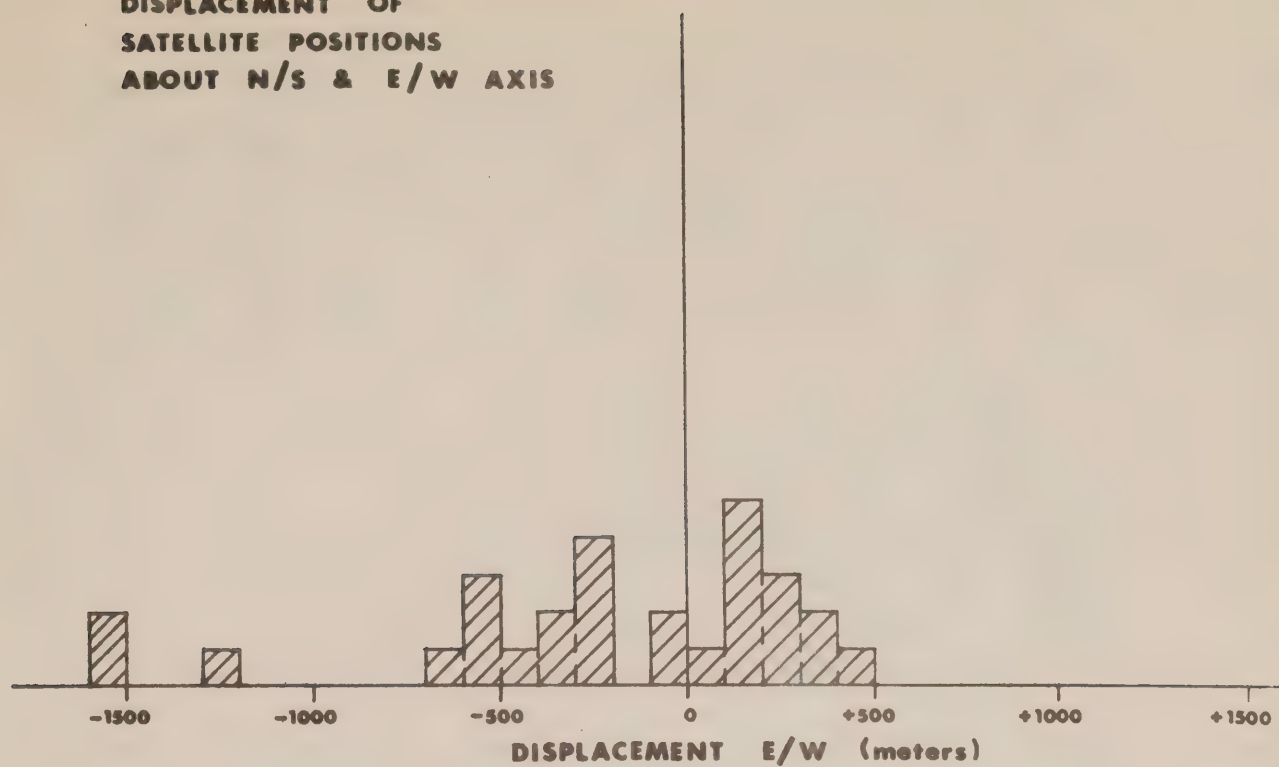
LINEAR DISPLACEMENT OF SATELLITE POSITION FROM RADAR POSITION



DISPLACEMENT IN METERS (hundreds)

JUAN DE FUCA STRAIT

DISPLACEMENT OF SATELLITE POSITIONS ABOUT N/S & E/W AXIS



1 DISPLACEMENT OUTSIDE
LIMITS OF HISTOGRAM

Fig. 19

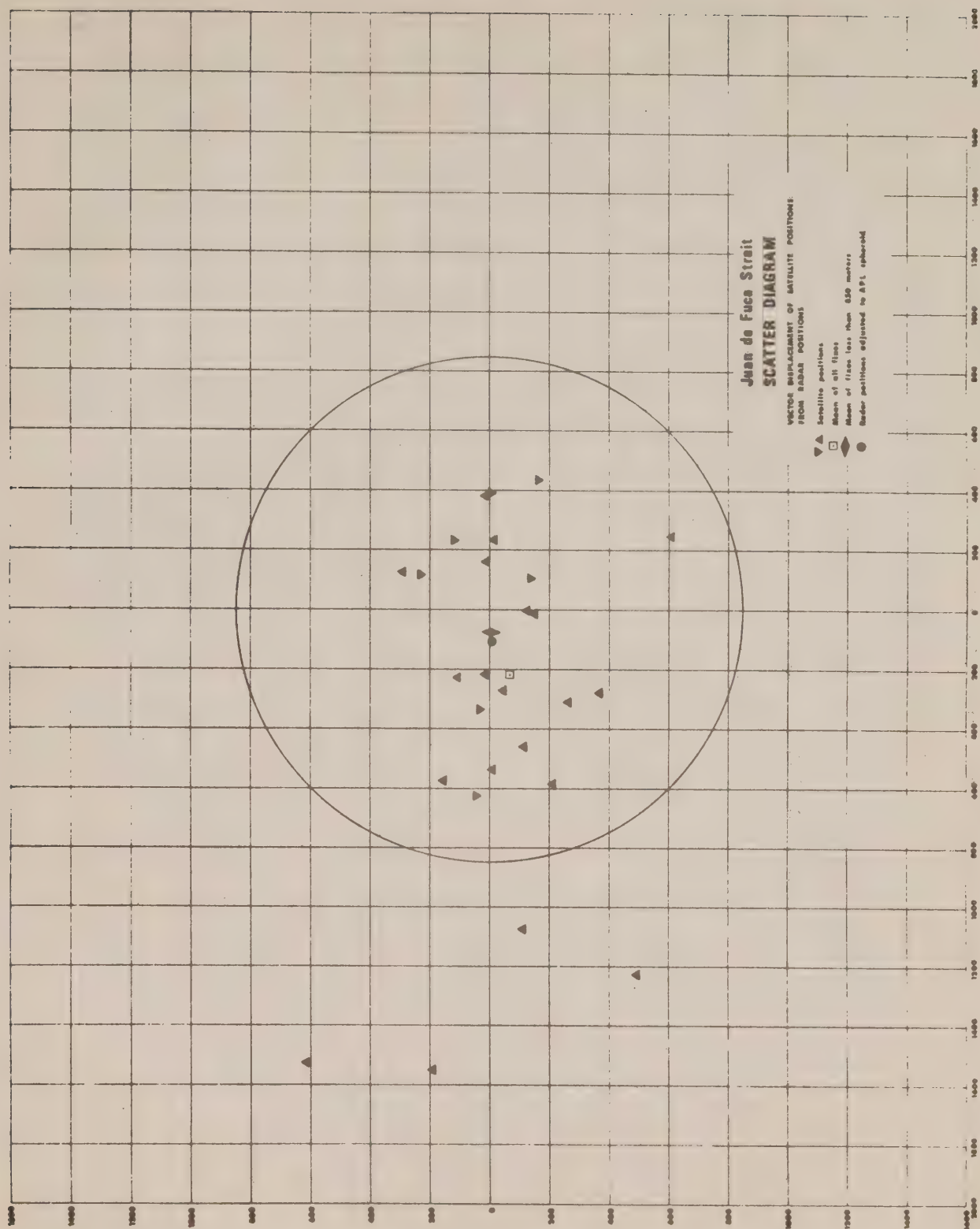


Fig. 20

©
INFORMATION CANADA
OTTAWA 1972

24813

